ASSESSMENT OF WATER STRESS ON RICE LANDRACES FROM DIFFERENT AGRO-CLIMATIC ZONES IN FARWEST NEPAL

A Dissertation Submitted for the Partial fulfillment of the Requirement for the Master's Degree in Science, Central Department of Botany

Submitted by

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DECLERATION

Thesis entitled **"Assessment of water stress on rice landraces from different agro-climatic zones in far-west Nepal"**, which is being submitted to the Central Department of Botany, Institute of Science and Technology (IOST), Tribhuvan University (TU), Nepal for the award of the Master's degree, is a research work carried out by me under supervision of Prof. Dr. Ram Kailash Prasad Yadav of Central Department of Botany, Tribhuvan University and under the co-supervision of Associate Prof. Dr. Chandra Prasad Pokhrel and Associate Prof. Dr. Lal B. Thapa, CDB TU.

This research is original and has not been submitted earlier in part or full in this or any other form to any university or institute, here or elsewhere, for the award of any degree.

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RECOMMENDATION

This is to recommend that **Nabin Lamichhane** has carried out research entitled "Assessment of water stress on rice landraces from different agro-climatic zones in far-west Nepal" for the award of Master's Degree in Botany under our supervision. To our knowledge, this work has not been submitted for any other degree.

He has fulfilled all the requirements laid down by the Institute of Science and Technology (IOST), Tribhuvan University, Kritipur for the submission of the thesis for the award of Master's degree.

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LETTER OF APPROVAL

On the recommendation of Prof. Dr. Ram Kailash Prasad Yadav, and co-supervisors Dr. Chandra Prasad Pokhrel and Dr. Lal B. Thapa, this Master's thesis submitted by Nabin Lamichhane, entitled "Assessment of water stress on rice landraces from different agro-climatic zones in far-west Nepal" is forwarded to the Dean, IOST, T.U.

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ABSTRACT

Rice holds a significant position globally as the second most essential staple food, and in Nepal, it stands as the primary food source. Its cultivation demands considerable water. However, the growing prevalence of drought due to climate change poses a severe threat to rice production, particularly affecting Nepal's food security. Indigenous landraces, adapted to local microclimates, could potentially possess drought-tolerant qualities. Hence, this study focuses on assessing the response of selected rice landraces from the Far-west region of Nepal to drought conditions. The research covers three distinct agroclimatic zones of the region: Tarai, inner Tarai, and midhills. From each zone, four varieties were chosen, amounting to a total of 12 varieties. Each variety underwent three treatments: control, intermittent drought, and complete drought, with five replications for each treatment. The experiments were done under the plastic tunnel in farmers field. A range of morpho-agronomic variables such as tiller count, root length, hill height, shoot and root weight, panicle length, grain count per panicle, total filled and unfilled grain count per panicle, and yield were measured. Additionally, chlorophyll content and catalase activity were measured as biochemical parameters. Drought tolerance indices were calculated based on these measurements.

Under water stress, most rice landraces decrease in tiller number, root length, and hill height. However, these landraces were able to maintain stable root and shoot weights despite the stressful conditions. While panicle length was reduced due to water stress, the number of grains per panicle remained consistent. This resulted in compromised yield under such stress condition. At the biochemical level, these rice landraces showed resilience by retaining their chlorophyll content and sustaining photosynthesis even during water stress. The range of the total chlorophyll was found to be 0.72 - 4.78 µg/g FW. The range of the catalase activity 0.14 – 0.51units/min/gram FW. Interestingly, landraces responded to water stress by increasing catalase activity, a sign of adaptation to cope with the stress. Based on drought indices, the Jhumke variety from Baitadi, Batebudo variety from Dadeldhura, and Sauthyari variety from Kanchanpur exhibited higher drought tolerance. It is recommended to extend the screening of drought tolerance to other rice landraces that are yet to be characterized and assessed for drought tolerance. The findings hold practical implications for local farmers and stakeholders.

Key words: Rice-landraces, Water-stress, Agro-morphonomic traits, Drought tolerance, Crop resilience

सारांश

धान नेपालको प्रमुख खाध्यबालि हो, विश्वव्यापि रुपमा पनि यसले दोस्रो स्थान ओगटेको छ । धान खेतिको लागि उल्लेख्य मात्रामा पानिको आवश्यकता पर्दछ । जलवायु परिवर्तन जन्य कारणहरुले गर्दा खडेरिको प्रकोप बढिरहेको आवस्थामा यसको धान उत्पादनमा नकरात्मक असर पर्न गइ नेपालको खाध्य सुरक्षामा गम्भिर असर परेको देखिन्छ । यस परिप्रेक्षमा धानका रैथाने जातहरु स्थानिय वातावरणमा सजिलै अनुकुलित हुने भएकाले , लामो समयदेखि स्थानिय वातावरणमै सुख्का सहन गर्न सक्ने क्षमता विकास गरेका धानका प्रजातिहरुको खोज अनुसन्धान गर्नु पर्ने अपरिहार्याता छ ।

अतह , यस अनुसन्धानले सुदुर पश्चिम प्रदेशका पाहाडी क्षेत्र (बैतडी जिल्ला), भित्री मधेश (डडेल्धुरा जिल्ला) र तराई (कन्चन्पुर जिल्ला) क्षेत्रमा सुक्का सहन गर्न सक्ने आंकलन गरिएका १२ प्रजातिहरुको सुक्कामा देखाउने प्रतिकृयाको बारेमा परिक्षण गरिएको छ। यस अनुसन्धानमा , टनेल भित्र ३ किसिमका पानिको मात्रामा धानखेतिको परिक्षण गरिएको थियो । तिन किसिमको पानिको मात्राहरुमा १. निरन्तर सिँचाई २. धान ओइलाएपछि सिँचाई ३. निरन्तर सुक्का रहेका थिय।

यस अनुसन्धानमा धानका प्रजातीअनुसार बिभिन्न प्रयोगमा फरक फरक प्रतिकृया देखाएको पाईएको थियो। समग्रमा, सुक्काको अवस्थामा धैरै जसो प्रजातिहरुको गाँज सानो हुने , जरा छोटो हुने , उचाई कम हुने लक्षण देखिएता पनि डाँठ र जराको तौलमा भने कुनै तात्विक फरक परेको देखिएन । त्यसैगरि उत्पादन सम्बन्धित विशेषताहरु विश्लेषण गर्दा सुक्काले धानमा बालाको लम्बाई घटेको र उत्पादकत्वमा ह्रास आयतापनि बालामा दानाको संख्यामा भने तात्विक फरक परेको देखिएन। खडेरि सुचाङकका आधारमा बैतडि जिल्लाको झुम्के जात, डडेल्धुरा जिल्लाको बातेबुढो र कन्चन्पुरको सौठ्यारि जातले बढि सहनशिलता देखाएका थिय। यस अनुसन्धानका परिणामहरुले स्थानिय किसान , सरोकारवालाहरु र निति निर्माताहरुलाइ टेवा पुग्ने छ । यसैगरि स्थानिय रैथाने जातको खोज, अभिलेखिकरण र उनिहरुमा पाइने विशेष्ताहरुको परिक्षण गर्न सिफारिस गरिन्छ ।

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ABBREVATIION AND ACRONYMS

^{o}C	:	Degree centigrade
ANOVA	:	Analysis of variance
CD	:	Complete drought
cm	:	Centimeter
DF	:	Degree of freedom
DRI	:	Drought resistance index
FW	:	Fresh weight
g	:	Gram
GP	:	Geometric mean productivity
GPS	:	Global positioning system
ha	:	Hectare
ID	:	Intermittent drought
m	:	Meter
min	:	Minute
MP	:	Mean productivity
n	:	Number of sample
No.	:	Number
p	:	Level of significance
PC	:	Principal component
pH	:	Potential of hydrogen
QGIS	:	Quantum geography information system
SD	:	Standard deviation
STI	:	Stress tolerance index
Tukey HSD	:	Tukey's honestly significant difference
YI	:	Yield index

1. INTRODUCTION

Rice is one of the most important staple foods worldwide, providing sustenance to over 3.5 billion people and playing a vital role in ensuring food security and supporting the livelihoods of local communities (Gadal et al., 2019). With its wide consumption and high nutritional value, rice contributes significantly to the global dietary energy supply, accounting for 20 percent (Alexandratos and Jelle, 2012). The commercial species of rice, *Oryza sativa* L., is differentiated into three sub-species: *indica*, *japonica*, and *javanica* based on their geographical distribution and production zones (Gadal et al., 2019). Sub-species *indica* varieties are cultivated in tropical and sub-tropical regions of South and Southeast Asia, as well as Southern China. Sub-species *japonica* is grown in temperate areas such as Japan, China, Nepal, and Korea, while sub-species *javanica* varieties are found in Indonesia (Gadal et al., 2019).

In the context of Nepal, rice cultivation holds immense significance as a staple food crop, occupying 32% of the country's agricultural land and engaging approximately 70% of households in rice farming for their daily needs (Kharel et al., 2018; Joshi et al., 2017). In 2018, rice cultivation covered 1.49 million hectares of land, resulting in an average productivity of 3.5 tons per hectare and a total annual production of 5.6 million tons (MoALD, 2019). However, the annual demand for milled rice in Nepal exceeds its production, leading to imports of around 0.75 million tons in 2019 (TEPC, 2020). In fact, rice imports have been escalating at a rate of 24.48% in quantity and 38.11% in value annually, while the growth rate of rice production has remained relatively stagnant at less than 2% per year. These statistics highlight the pressing need for effective strategies to address the challenges faced in rice cultivation (Gairhe et al., 2021).

Water scarcity is becoming a growing concern globally, and it is estimated that by 2025, approximately 15 million hectares of land will face physical water scarcity, with an additional 22 million hectares experiencing economic water scarcity (Liu et al., 2013). It's one of the major impacts will be on agriculture, leading to drought conditions and ultimately food insecurity (Prasad et al., 2011; Dai, 2013; Liu et al., 2013). Drought stress poses a significant threat to global rice production and food security. In light of this situation, special attention must be given to moisture-loving plants, such as rice, as they play a crucial role in feeding a significant portion of the global population. To ensure their viability in future water-scarce agricultural practices, strategies need to be implemented (Ungureanu et al., 2020).

Nepal’s diverse climate is a result of its unique topography and altitudinal variation, which supports a wide range of agro-climatic zones (Paudel et al., 2021). The agriculture system in Nepal is facing numerous challenges, including the increasing occurrence of drought (Gaire et al., 2021). Droughts in Nepal have become more severe, frequent, and prolonged since the 2000s (Sharma et al., 2021; Bagale et al., 2021). The frequency of drought events, particularly since 2005, has had a significant impact on rice cultivation, leading to delays in transplanting and harvesting (Bagale et al., 2021; Gahatraj et al., 2018).

The drought events have profound detrimental effects on rice production and the overall agricultural system. The research conducted by Sharma et al. (2021) demonstrated that between 1980 and 2016, the cumulative probabilities of both short-term and long-term droughts in Nepal were found to be 17.1% and 23.5%, respectively, pointing towards a noticeable increase in the prevalence of droughts over time. This finding is further supported by Bagale et al. (2021), who solidified the evidence of an escalation in drought frequency in Nepal since 2005. Utilizing the standard precipitation index data from 1997 to 2018, Similarly, Dahal et al. (2016) reported an increased severity and frequency of droughts in Nepal over a 32-year period. The climate-induced drought in Nepal’s hill farming system presents significant challenges to agriculture, livelihoods, and social dynamics, emphasizing the urgent need for effective adaptation measures (Adhikari, 2018). Specific regions in Nepal, particularly the far and mid-western regions, have experienced extreme drought events, with the far western region facing a higher frequency of droughts and the mid-western region experiencing more severe droughts during periods of low precipitation (Kafle, 2014). The Far-west region, including districts like Kailali, Kanchanpur, and Dadeldhura, suffers from water scarcity issues, exacerbating the impact of droughts on agriculture (Paudel et al., 2021).

The impact of climate-induced drought on Nepal's farming system raises significant challenges for agriculture, livelihoods, and social dynamics (Adhikari, 2018). It highlights the urgent need to implement effective adaptation measures (Adhikari, 2018). In particular, rice farming in the far-west region of Nepal is greatly affected by drought events caused by rising temperatures and decreasing rainfall patterns (Paudel et al., 2021). These droughts have detrimental consequences for rice production and the agricultural system as a whole (Gahatraj et al., 2018). The drought result in delays in transplanting and harvesting activities and necessitate the adoption of climate-resilient rice varieties to mitigate these effects (Gahatraj et al., 2018).

Drought stress significantly affects rice plants at all stages of growth, leading to various negative consequences such as reduced germination potential, hindered seedling vigor, decreased tillering, and lowered grain yield (Moonmoon and Islam, 2017; Kızılgeçi et al., 2017; Rhaman and Ellis, 2019). Rice plants respond to drought by accumulating specific substances like cellular compatible solutes and antioxidants, that help them combat the stress and protect against cellular damage (Usman et al., 2013; Sokoto and Muhammad, 2014; Yang et al., 2014; Maghsoodi et al., 2015; Pandey and Shukla, 2015; Nasrin et al., 2020). Drought stress affects negatively on various physiological processes in plants, including water uptake, photosynthesis, transpiration, and nutrient absorption (Boyer, 1997; Chaves et al., 2009). Prolonged periods of water scarcity can lead to severe damage to rice plants, inhibiting their growth and development and resulting in substantial yield losses (Chaves et al., 2009). Drought stress severely affects rice plants by reducing water availability, hindering normal physiological processes, and causing significant yield losses. Moreover, prolonged drought conditions can overwhelm the plant's defense mechanisms, resulting in yield losses and economic hardships for farmers (Jing et al., 2019; Nasrin et al., 2020).

To address the challenges posed by drought and enhance the resilience of rice cultivation, research efforts have focused on exploring drought-tolerant landraces, which have gained significant importance (Mishra et al., 2019, Behera et al., 2023).Landraces are traditional varieties that have adapted to specific environmental conditions over time (Zeven 1998), exhibiting remarkable resilience to both biotic and abiotic stresses. These landraces serve as valuable genetic resources for breeding programmes aimed at developing improved varieties with enhanced drought tolerance (Azeez et al., 2018). They possess unique traits that enable them to withstand water scarcity, such as deep root systems, reduced transpiration rates, and enhanced water-use efficiency (Gairhe et al., 2021; Venuprasad et al., 2007). Furthermore, Nepal has a diverse ecological conditions, meaning that not all crop cultivars are suitable for every region (Kandel and Shrestha, 2020). Therefore, it is necessary to conduct specific drought screening trials in each different agroclimatic region before recommending a cultivar for that particular area (Kandel et al., 2022).

Stress-tolerant landraces currently face significant challenges due to limited studies focused on identification, characterization, and documentation. The emphasis on high-yielding short-life cycle and aromatic varieties, along with the promotion of hybrids and exotic varieties for commercial purposes, has resulted in the neglect of traditional landraces (Kandel and Shrestha, 2020). Moreover, the distribution of untested exotic varieties by agricultural departments and Agriculture Knowledge Centers (Krishi Gyan Kendra) has worsened the situation further leading to a gradual decline in landrace variety (Kandel and Shrestha, 2020). To prevent irreversible loss of invaluable genetic diversity present in stress-tolerant landraces, it is crucial that we prioritize their identification, accurate characterization, and thorough documentation. By doing so we can ensure preservation of these traditional varieties thus facilitating their integration into future breeding programs. Ultimately this would promote sustainable agricultural practices and enhance crop resilience specifically targeting drought stress conditions.

The study aims to examine the effects of drought on indigenous rice landraces in Nepal's Far-west region, an area prone to water scarcity. By identifying and characterizing resilient landraces that can withstand drought conditions, valuable insights can be gained regarding their specific biochemical and physiological traits that contribute to their resilience and impact on yield. These findings will significantly contribute to improving breeding strategies and the development of new varieties of rice that are tolerant to drought. This is crucial for adapting to climate change challenges and recurring periods of drought in Nepal's rice-growing areas. Ultimately, the research aims to enhance the sustainability and productivity of rice cultivation, ensuring food security, as well as enhancing local farmers' livelihoods.

1.1 Theoretical background of drought assessment

Drought stress in rice plants leads to a series of adaptive responses aimed at minimizing water loss and maintaining cellular homeostasis. One of the primary responses is stomatal closure, which reduces water loss through transpiration (Boyer, 1997; Chaves et al., 2003). Drought stress also affects various physiological processes in plants, including water uptake, photosynthesis, transpiration, and nutrient absorption (Boyer, 1997; Chaves et al., 2003). Additionally, drought stress triggers alterations in photosynthetic activity, such as changes in the efficiency of photosystem II and the synthesis of protective molecules like antioxidants. These adjustments optimize energy use and protect cellular components from oxidative damage. Consequently, drought stress significantly impacts rice plants at all stages of growth, leading to detrimental effects such as reduced germination potential, hindered seedling vigor, decreased tillering, and lowered grain yield (Moonmoon and Islam, 2017; Kızılgeçi et al., 2017; Rhaman and Ellis, 2019).

To combat drought stress, rice plants accumulate specific substances that help them tolerate the stress and protect against cellular damage (Usman et al., 2013; Sokoto, 2014; Yang et al., 2014; Pandey and Shukla, 2015; Nasrin et al., 2020). Drought tolerance in rice is a complex trait influenced by multiple genes and developmental stages (Rasheed et al., 2020). The genetic basis of drought tolerance involves various genes and signaling pathways (Panda et al. 2021). Dehydration-Responsive Element Binding (DREB) and Myeloblastosis (MYB) transcription factors play critical roles in controlling the expression of stress-responsive genes, which results in a production of osmoprotectants, stress proteins, and enzymes involved in stress signaling. These molecular responses enable rice plants to maintain cellular water potential, protect cellular structures, and modulate metabolic processes under drought conditions (Panda et al. 2021).

In the context of crop adaptation to drought stress, rice landraces, with their long history of adaptation to specific agro-climatic conditions, possess unique genetic variations that contribute to their drought tolerance. Exploring the genetic diversity of rice landraces and characterizing their morpho-physiological and biochemical traits provide insights into the mechanisms underlying drought tolerance and guide breeding efforts to develop improved varieties (Mir et al., 2012; Dixit et al., 2014).

In summary, the study of drought tolerance in rice landraces is rooted in the theoretical framework of plant stress physiology and crop adaptation. Drought stress triggers a series of physiological responses in rice plants, including stomatal closure, reduced photosynthetic activity, and altered metabolic pathways. These responses are regulated by various genes and pathways associated with drought tolerance (Fig: 1). Understanding the genetic basis and physiological mechanisms of drought tolerance in rice landraces can inform breeding strategies aimed at developing drought-tolerant varieties with improved yield potential.

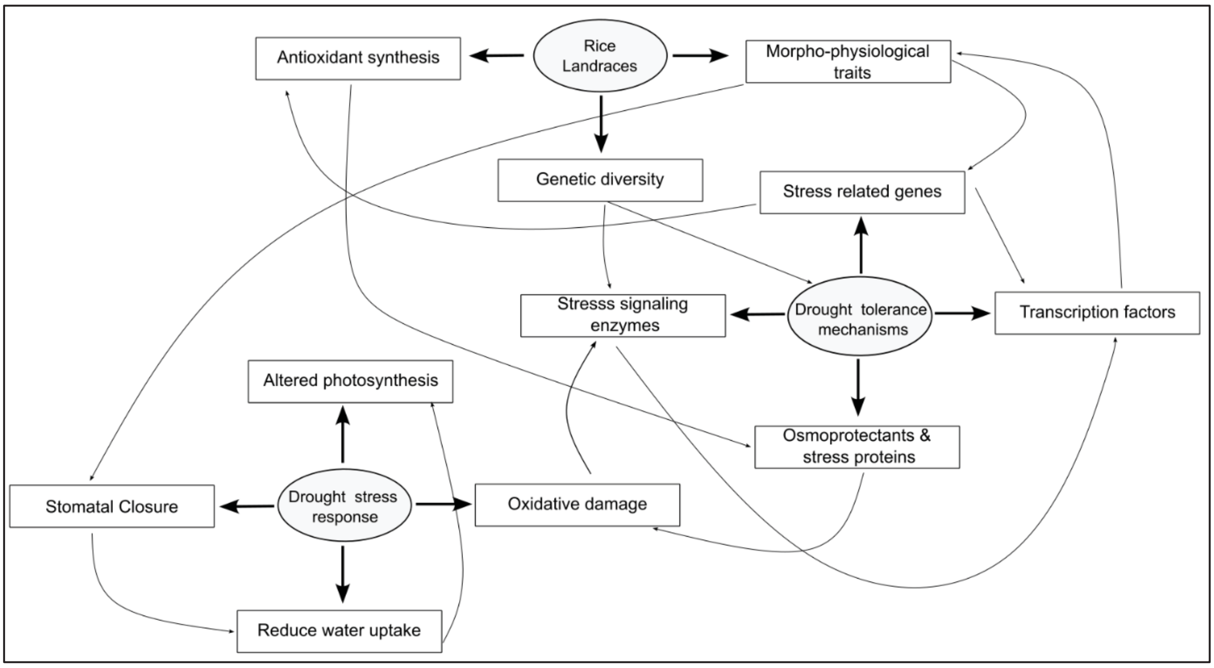

Fig. 1 Conceptual framework

1.2 Drought stress in rice cultivation

Drought stress in rice cultivation is a serious limiting factor that results in significant economic losses, and its impact is expected to worsen due to global climate change (Panda et al., 2021). The scarcity of water resources poses a growing concern, with estimates suggesting that by 2025, millions of hectares of land will face physical and economic water scarcity, leading to drought conditions and food insecurity (Liu et al., 2013; Ungureanu et al., 2020). In this context, rice, as a moisture-loving plant and a vital food source for a significant portion of the global population, requires special attention to ensure its viability in future water-scarce agricultural practices (Ungureanu et al., 2020).

Drought stress significantly affects various growth parameters and yield components in rice plants. It negatively impacts germination rate, seedling vigor, shoot and root growth, leaf area, tiller and spikelet formation, grain weight, yield, and seed quality (Shinozaki and Yamaguchi-Shinozaki, 2007 ; Kızılgeçi et al., 2017; Moonmoon and Islam, 2017; Rhaman and Ellis, 2019; Mukamuhirwa et al., 2019). Under drought conditions, rice plants respond by accumulating cellular compatible solutes, growth substances, and antioxidants to combat stress and protect against cellular damage (Usman et al., 2013; Sokoto, 2014; Yang et al., 2014; Maghsoodi et al., 2015; Pandey and Shukla, 2015; Nasrin et al., 2020). However, drought stress also leads to an increase in the level of malondialdehyde (MDA), which damages cell membranes (Usman et al., 2013; Sokoto, 2014; Yang et al., 2014; Maghsoodi et al., 2015; Pandey and Shukla, 2015; Nasrin et al., 2020).

The development of drought-tolerant rice varieties is crucial to mitigate the negative effects of drought stress. Drought tolerance in rice is a complex trait influenced by multiple genes and developmental stages (Rasheed et al., 2020). Recent progress has been made in understanding the physiological, biochemical, and molecular adaptations of rice to drought stress, providing valuable insights for future crop improvement programmes (Panda et al., 2021; Rasheed et al., 2020; Yang et al., 2022). Evaluating the extent of damage in various traits provides a useful method for screening drought-tolerant genotypes and identifying resilient varieties that can withstand drought stress (Pandey and Shukla, 2015; Islam et al., 2018; Neelam et al., 2018).

So, drought stress in rice cultivation poses significant challenges and negatively affects various aspects of rice production and yield. Addressing water scarcity and developing drought-tolerant rice varieties through genetic improvement are crucial for ensuring sustainable rice production and food security in the face of climate change (Panda et al., 2021; Ungureanu et al., 2020).

1.3 Genetic diversity and rice landraces, as drought resilient

Ancient and adaptable crop varieties known as landraces are gaining renewed attention due to the limitations of modern agriculture (Marone et al., 2021). These landraces, also referred to as native varieties (Divya, 2020), thrive in challenging environments and possess valuable genetic diversity that can enhance crop resilience and productivity (Marone et al., 2021).

The utilization of landraces in breeding programs presents an opportunity to improve the resilience of rice crops, reduce vulnerability, and contribute to long-term food security (Hour et al., 2020). These old crop varieties, which have adapted to stress environments, serve as valuable sources of abiotic stress resistance traits (Turin et al., 2023). Through on-farm practices, landraces are conserved, enabling researchers and breeders to unlock their potential through careful analysis (Marone et al., 2021).

When the variability of elite breeding materials becomes exhausted, landraces can be utilized due to their genetic diversity and specific traits like drought tolerance (Turin et al., 2023). The conservation of traditional landraces through on-farm practices and gene banks allows researchers and breeders to harness their potential through careful analysis (Marone et al., 2021). By incorporating beneficial traits from landraces into modern crops through genomics, we can create more resilient and sustainable agricultural systems that are better equipped to cope with climate change (Marone et al., 2021; Turin et al., 2023). Cereal landraces, in particular, offer a hope for a brighter future in farming (Marone et al., 2021), and breeding efforts should prioritize utilizing them to address traits such as drought tolerance (Turin et al., 2023).

The study and identification of drought-tolerant landraces provide researchers and breeders with the opportunity to develop improved rice varieties that are well-suited to environmental conditions (Gahatraj et al., 2018). Furthermore, the utilization of landraces in breeding programs contributes to the resilience of rice crops, reduces vulnerability, and supports long-term food security (Shrestha et al., 2020).

Identification of appropriate physiological stress tolerance mechanism and the genetic improvement of drought tolerance in crop plants need great attention (Sujit and Sarkar, 2003). The genetic resources of agriculture cops, including traditional varieties, wild relatives, native species, and modern cultivars, form the foundation of global food security (Divya 2020). Genetic diversity enables farmers, plant physiologists, breeders, and biotechnologists to develop resistant crops through natural selection, breeding, and genetic manipulation, adapting to changing environments (Divya 2020). Identifying stress-tolerant traditional crop races and genetically manipulating plants for improved photosynthesis, foliage growth, and yield under stress conditions are areas that require attention (Condon et al., 2004).

1.4 Parameters used for study of drought response in rice

Various screening methods have been employed to identify drought-tolerant rice varieties. These methods encompass the evaluation of morphological, physiological, and biochemical traits associated with drought tolerance (Sujit and Sarkar 2003; Usman et al., 2013; Moonmoon and Islam, 2017; Nahar et al., 2018; Divya 2020, Kandel et al. 2022; Bhandari et al. 2023). Parameters such as root length, shoot length, panicle characteristics, biomass accumulation, chlorophyll content, proline accumulation, and catalase activity have been used to assess drought tolerance in rice plants (Usman et al.,2013; Nahar et al., 2018; Saha et al., 2020; Kandel et al.,2022; Kumar et al., 2023). These screening methods facilitate the identification of promising rice landraces with enhanced drought tolerance.

1.4.1 Root and shoot length

Root length is an important factor in screening methods for drought tolerance in rice due to its significant influence on shoot growth and grain yield under drought stress (Panda et al., 2021). *O. sativa* exhibits diverse root architectures and responses to environmental conditions, with root development strongly influenced by factors such as the presence of dense soil layers and severity of drought stress (Gowda et al., 2011; Panda et al., 2021). Variations in root growth characteristics, including increased root length associated with higher abscisic acid concentration, are observed in response to water stress (Gowda et al., 2011; Panda et al., 2021). Measuring root length is a valuable approach to evaluate the plant's ability to develop a strong and extensive root system, allowing for better access to soil moisture during water scarcity (Usman et al., 2013; Nahar et al., 2018; Saha et al., 2020; Kandel et al., 2022). Assessing root length helps in identifying drought-tolerant rice landraces and facilitates the development of more resilient and drought-tolerant rice varieties.

O. sativa, with its diverse genetic diversity, shows varying root architectures and responses to environmental conditions (Gowda et al., 2011; Panda et al., 2021). So the root development is strongly influenced by environmental factors such as the presence of dense soil layer and severity of drought stress (Gowda et al., 2011). Under drought stress, the morpho-physiological characteristics of rice roots have a considerable impact on shoot development and total grain output (Panda et al., 2021). That is why root length is a crucial factor for studying the response of drought in rice. Genotypes with profound roots, coarse roots, extensive branching, and high root-to-shoot ratio are important for drought tolerance in rice (Panda et al., 2021).

Variations in root growth characteristics are observed in response to water stress, with increased root length associated with higher abscisic acid concentration (Panda et al., 2021; Gowda et al., 2011). It involves measuring the length of the roots to evaluate the plant's ability to develop a strong and extensive root system (Usman et al., 2013; Nahar et al., 2018; Saha et al., 2020; Kandel et al., 2022). A longer root length indicates that the rice plant can explore a larger volume of soil, enabling it to access deeper layers for water uptake during periods of water scarcity (Kandel et al., 2022). By assessing root length, we can identify rice landraces that show promising characteristics for withstanding drought conditions and potentially contribute to the development of more resilient and drought-tolerant rice varieties.

Under drought stress conditions, the shoot length of rice plants is commonly reduced, indicating the adverse effects of water scarcity on plant growth and development (Kumar et al., 2023; Yadav et al., 2023). Assessing shoot length provides valuable insights into the plant's ability to maintain elongation and growth despite limited water availability (Nahar et al., 2018, Kandel et al., 2022)

1.4.2 Panicle characteristics

Panicle characteristics play a significant role in assessing drought tolerance in rice plants (Kandel et al., 2022). Various aspects of the panicle, such as panicle length, filled and non-filled grains, weight of 1000 grain weights, and the weight of grains per panicle, provide valuable insights into the plant's ability to withstand drought stress and maintain reproductive performance (Usman et al., 2013; Nahar et al., 2018; Yadav et al., 2023).

Drought stress often leads to a reduction in panicle length, indicating the impact of water scarcity on panicle development (Panda et al., 2021; Kandel et al., 2022; Kumar et al., 2023; Yadav et al., 2023). Additionally, drought can result in a decrease in the number of filled grains, affecting grain yield (Panda et al., 2021). The drought also influence the weight of 1000 grain, which represents individual grain size and weight (Panda et al., 2021). Under water-limited conditions, the weight of 1000 grain tends to decrease (Panda et al., 2021; Kumar et al., 2023; Yadav et al., 2023).

1.4.3 Biomass accumulation

Biomass accumulation is an important parameter in assessing drought tolerance in rice plants. It provides insights into the overall growth and development of the plant under water-limited conditions. Drought stress can significantly impact biomass accumulation, affecting both the shoot and root systems (Hussain et al., 2021, Kandel et al., 2022). The water stress significantly reduced the biomass and the quality of biomass in susceptible variety (Hussain et al., 2021) The fresh weight and dry weight of roots and shoots are commonly measured to evaluate biomass accumulation in rice plants exposed to drought stress (Panda et al., 2021).

Under drought conditions, the fresh weight of roots and shoots may be reduced, indicating a decrease in overall plant growth (Panda et al., 2021; Hussain et al., 2021). Similarly, the dry weight of roots and shoots, which represents the biomass after removing water content, can also be affected by drought stress (Zhang et al., 2018). Reductions in dry weight indicate impaired biomass accumulation and compromised plant growth due to water scarcity (Hussain et al., 2021). But the effect biomass accumulation, yield on the drought tolerance has not been the fully elucidated (Zhang et al., 2018)

1.4.4 Chlorophyll content

Chlorophyll content is a critical parameter for assessing the physiological response of rice plants to drought stress (Zhu et al., 2020; Panda et al., 2021). It reflects the plant's capacity to maintain photosynthetic activity and overall health under limited water conditions. Chlorophyll, comprising chlorophyll a and chlorophyll b, is responsible for light energy absorption during photosynthesis. Drought stress can disrupt the chlorophyll content in rice plants, impacting their photosynthetic capacity (Zhang et al., 2018; Panda et al., 2021). Quantification of chlorophyll a and chlorophyll b levels provides insights into the effects of drought on photosynthetic pigments, while total chlorophyll content represents the overall chlorophyll status in the plant (Zhu et al., 2020). Reduced chlorophyll content indicates potential damage to the photosynthetic machinery, compromising the plant's light energy capture and photosynthesis efficiency (Panda et al., 2021). Additionally, carotenoids, acting as antioxidants and photo protective agents, are crucial for mitigating drought-induced oxidative stress. Quantifying carotenoid levels provides valuable information on the plant's ability to cope with oxidative damage caused by drought (Ashraf and Harris, 2013).

1.4.5 Catalase activity

Catalase (CAT) is an antioxidant enzyme found in aerobic organisms, playing a versatile role in plants by efficiently converting hydrogen peroxide (H_2O_2) into water and oxygen (Sharma and Ahmad, 2014). It is present in various cellular compartments of higher plants, such as peroxisomes, mitochondria, cytosol, and chloroplasts, highlighting its diverse functions within the plant system (Sharma and Ahmad, 2014; Lum et al., 2014). The multiple forms of catalase isozymes, including CAT-1, CAT-2, and CAT-3, are encoded by specific structural genes, and their modulation at different cellular locations and developmental stages plays a crucial role in plant signal transduction (Sharma and Ahmad, 2014). Deficiency in catalase can lead to various detrimental effects such as chlorosis, sterility, and increased sensitivity to photo respiratory conditions (Sharma and Ahmad, 2014; Saha et al., 2020). Additionally, studying the molecular phylogeny of plant catalase proteins provides valuable insights into the structural and functional relationships among diverse plant species (Sharma and Ahmad, 2014).

Plants often face oxidative stress caused by drought conditions, leading to an imbalance in cellular redox homeostasis and the accumulation of reactive oxygen species (ROS), including H_2O_2 (Lum et al., 2014; Ali et al., 2021). Elevated levels of H_2O_2 can result in oxidative damage to vital cellular components, including proteins, lipids, and nucleic acids, ultimately impairing physiological functions and reducing overall plant performance (Sharma and Ahmad, 2014). However, catalase acts as a critical defense enzyme by rapidly decomposing H_2O_2, preventing its accumulation, and minimizing oxidative damage (Saha et al., 2020; Ali et al., 2021). Through its catalytic activity, catalase efficiently converts H_2O_2 into water and oxygen molecules, thereby maintaining cellular redox balance and providing protection against oxidative stress (Ali et al., 2021).

The activity of catalase serves as a reliable indicator of a plant's ability to scavenge H_2O_2 and tolerate drought stress (Saha et al., 2020). Higher catalase activity is associated with improved drought tolerance in plants, as it signifies an enhanced capacity to counteract oxidative damage and maintain cellular integrity (Lum et al., 2014; Saha et al., 2020). Therefore, assessing catalase activity in rice plants provides valuable insights into their antioxidative defense system and adaptation strategies under drought conditions (Saha et al., 2020). Moreover, understanding the regulation and modulation of catalase activity can aid in the identification of rice genotypes with superior antioxidative capacity and improved resilience to water stress.

1.5 Status of rice in Nepal

A total of 8389 rice accessions from Nepal have been preserved across various national and international genebanks (Kandel and Shrestha, 2018). Within this extensive collection , only approximately 2500 rice accessions have undergone characterization by agro-morphological traits and biochemical markers, but remaining germplasm are not characterized and they awaits their characterization (Kandel and Shrestha, 2018).

Besides this, the Government of Nepal has released and registered 97 rice varieties (Gautam and Dhungel, 2016), of which 12 have been again notified for being unsuitable for cultivation (Devkota et al., 2016). As of 2016, 30 hybrid rice varieties have been registered by the National Seed Board (NSB) (Devkota et al., 2016). Ten of these improved and hybrid varieties have been released as drought-tolerant varieties, including Hardinath-2, 6 varieties of Sukkhadhan (1-6), Swarna sub-1, and Samba mansuli Sub-1 (Yadav et al., 2016). However, there are many other rice landraces in Nepal that have the potential to tolerate drought. These landraces should be characterized and documented and identified for developing new drought-tolerant rice varieties. Rice is cultivated in 32 % percentage of countrys agricultural land, which engages 70% of housedholds in rice farming (Joshi et al., 2017 ; Kharel et al., 2018) however the production is not sufficient , Nepal has imported 0.75 million tons of rice annually (TEPC, 2020).

1.6 Research gap

Reviewing the existing literature reveals several research gaps that need to be addressed. Firstly, there is a scarcity of studies specifically investigating the effect of water stress of rice landraces in the selected agroclimatic zones of Tarai, inner Tarai and mid hills. While some studies have explored drought tolerance in rice landraces from other regions, the unique agroclimatic conditions and genetic diversity of far-west Nepal necessitate focused research in this area.

Another research gap is the lack of comprehensive characterization of specific rice landraces from far-west Nepal in terms of their morpho-agronomic, and biochemical traits related to drought tolerance.

1.7 Justification of the study

The prevalence of drought and water scarcity is increasingly having a profound impact on rice, which serves as a crucial staple food globally. This situation poses significant implications for global food security since rice alone contributes to 20 percent of the worldwide dietary energy supply (Alexandratos and Bruinsma, 2012). In Nepal, frequent occurrences of drought have been observed, particularly in the Far-west region encompassing Kailali, Kanchanpur, and Dadeldhura (Sharma et al., 2021; Bagale et al., 2021). Considering the susceptibility of rice cultivation to water scarcity within this region, careful assessment and characterization of drought-tolerant landraces, suitable for cultivating rice in these areas, is essential.

Besides, the Far-west region of Nepal has been relatively less explored in terms of research, particularly concerning traditional rice landraces. Moreover, traditional rice landraces have been historically neglected for exploration and research in favor of high-yielding modern varieties (Kandal and Shrestha, 2020). But the landraces have evolved under the local environmental conditions and may possess unique adaptations to cope with drought stress and developed unique characteristics in response to the local microclimate conditions (Marone et al., 2021; Turin et al., 2023). By identifying, documenting, and characterizing rice landraces in this region, we not only enhance our understanding of local agro biodiversity but also contribute to the conservation of traditional rice varieties. By studying these landraces, we can uncover valuable traits that enable them to withstand water scarcity, potentially enhancing the resilience of rice crops in the face of climate change and increasing water stress.

The current study aims to undertake a comprehensive analysis of the impacts of drought on native rice landraces in the far-west regions, analyzing the key morphological and physiological characteristics that provide resilience to water stress. This study intends to uncover novel techniques for enhancing drought tolerance in rice cultivars by thoroughly characterizing these landraces. This study has the potential to significantly contribute to the creation of resilient rice varieties capable of navigating recurring drought situations by expanding our understanding of drought-responsive characteristics. As a result, this attempt is critical to guaranteeing food security and improving the well-being of local agricultural communities.

1.8 Hypothesis and Research questions

Hypothesis

The morpho-agronomic characteristics and biochemical properties of rice land races vary across different water stress conditions as well as different agro climatic zones of the region.

Research questions

The study is based the following research questions:

- What are the morpho-agronomic characteristics of rice landraces under water stress conditions?
- How do the biochemical parameters of these rice landraces respond to water stress?
- Which of the landraces exhibits the highest tolerance to water stress in the study area?

1.9 Objectives

Overall objective of the proposed research is to analyze the effects of different treatments of water stress (normal irrigation, intermittent irrigation and no irrigation) on selected rice landraces of far-west Nepal.

The specific objectives are:

- To analyze changes in the morpho-agronomic characteristics of rice landraces under water stress.
- To analyze the biochemical parameters of rice landraces under water stress.
- To identify and characterize drought-tolerant attributes of selected rice landraces.

1.10 Limitation

The limitation of the study area:

- Although there were number of rice landraces as identified by the local people as drought tolerant, altogether 12 rice landraces (four landraces at each Tarai, inner Tarai and mid hill reagion) were used for the study. These landraces were selected for the study on the basis of recommendation of most of the local people in the Kanchanpur, Dadeldhura and Baitadi districts of far-west Nepal.
- There are different agro-morphological and biochemical parameters that can be used for the study of drought response. This study focused on specific agro-morphological traits such as plant height, biomass, reproductive traits, chlorophyll content, proline concentration and catalase activities due to limitation in laboratory facility, time and budgetary constraints.

2. MATERIALS AND METHODS

2.1 Study sites

Three distinct agroclimatic zones in farwest-Nepal were selected for this study, including Tarai, inner Tarai, and Mid Hills (Table 1, Fig: 2). The Tarai is located in the southern part of the country and has a tropical climate with high temperatures and humidity during summers, making it habitat to a diverse range of crops including rice. Kanchanpur and Kailali are two districts in Tarai of far-west Nepal. The research station for this study in the Tarai zone was situated in Belauri Municipality of Kanchanpur district, characterized by its flat landscapes, fertile soil, and lower tropical zone classification according to Paudel et al. (2021). The station is located at 28.696 °N and 80.376 °E, at an altitude of 198 m from sea level.

Moving to the inner Tarai, it is situated between the Mahabharat range and the Chure hills. This region experiences a transitional climate with milder temperatures compared to the Tarai. The inner Tarai presents favorable agroclimatic conditions for crops like rice, wheat, maize, and vegetables, benefiting from its topographical features like valleys and basins that influence agroecological conditions. In farwest Nepal, Dadeldhura district represent the inner Tarai. Parshuram Municipality of Dadeldhura district was selected as the research station for the inner Tarai. The location of the station was 29.160° N and 80.286° E, at an altitude of 370 m from sea level.

The mid hills exhibit a temperate climate with cooler temperatures than the Tarai and inner Tarai and lies to northern side. This region showcases diverse agroclimatic variations, with crops like rice, maize, and millet thriving at lower elevations, while higher altitudes support the cultivation of temperate fruits such as citrus. The mid hills' agroecological conditions vary based on altitude and slope, they utilize terrace farming and other farming systems to maximize agricultural productivity. The research station for the mid hills zone was established in Patan municipality of Baitadi district, classified as an agro-climate zone of lower hills (1200-2200 m asl) with a warmer temperate climate, hillside terraces, and slopes according to Paudel et al. (2021). The specific locations of the experiment plots in Baitadi district are situated at 29.483° N - 29.478° N and 80.617° E - 80.614° E, at an altitude of at an altitude of 1550 - 1700 m from sea level (Table 1).

Table 1 Study area

S.N	Agroclimatic zone	District	Municipality	Lat/long of experiment plot	Altitude (masl)
1	Mid-hill	Baitadi	Patan Municipality	29.478°N - 80.617° E 29.483° N - 80.614° E	1666 m 1550 m
2	Inner-Tarai	Dadeldhura	Parshuram Municipality	29.160° N - 80.286° E	353 m
3	Tarai	Kanchanpur	Belauri Municipality	28.696° N - 80.376° E.	180 m

2.2 Climates of study site:

The experimental station in Baitadi exhibited a mean temperature of 16.9 ºC. The region experiences an average total annual precipitation of 1156 mm, with the highest rainfall recorded in July at 273.9 mm. In Dadeldhura, the average temperature was found to be 20.8 ºC . The area receives an annual average rainfall of 1593 mm, with the peak rainfall observed in July, reaching 418.0 mm. Moving to Kanchanpur district, the average temperature was notably higher at 27.1ºC. The region also received an annual total rainfall of 1593 mm. (Fig: 2)

2.3 Variety selection and seed collection

Four varieties of rice landraces were selected for experiment in each agroclimatic zones (Table 2), from the preliminary survey, those varieties which local people thought of having drought tolerance characters were selected for the experiment, in Kanchanpur the varieties were, "Sauthyari", "Ghiupuri", "Lalchand", "Anjana". Varieties from Dadeldhura are: "Chiudi", "Jhini", "Batebudo", "Shanti" and Baitadi are: "Chamade", "Jhumke", "Temase", "Ratomarso". (Table 2). The seeds were collected from local farmers. They used their own traditional way to store seeds.

Table 2 Selection of rice varieties in study area.

S.N.	Location	Varieties
1	Baitadi	Chamade, Jhumke, Ratomarso, Temase
2	Dadeldhura	Chiudi, Jhini, Batebudo, Shanti
3	Kanchanpur	Anjana, Lalchand, Ghiupuri, Sauthyrai

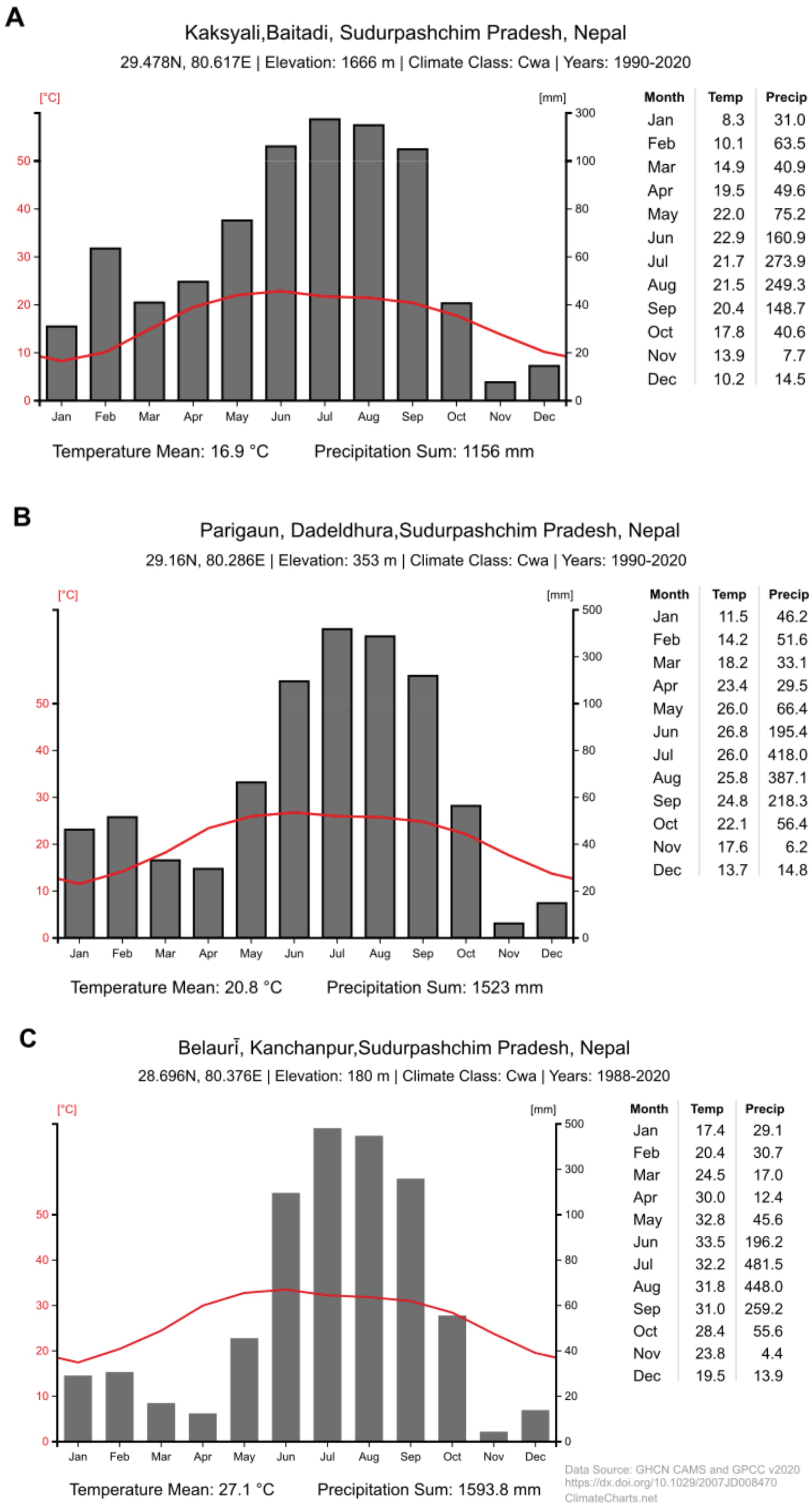

Fig. 2 Climatechart of the study area (Ombothermic graph). **A.** Baitadi **B.** Dadeldhura **C.** Kanchanpur (Obtained from climateCharts.net accessed on 7/8/2023)

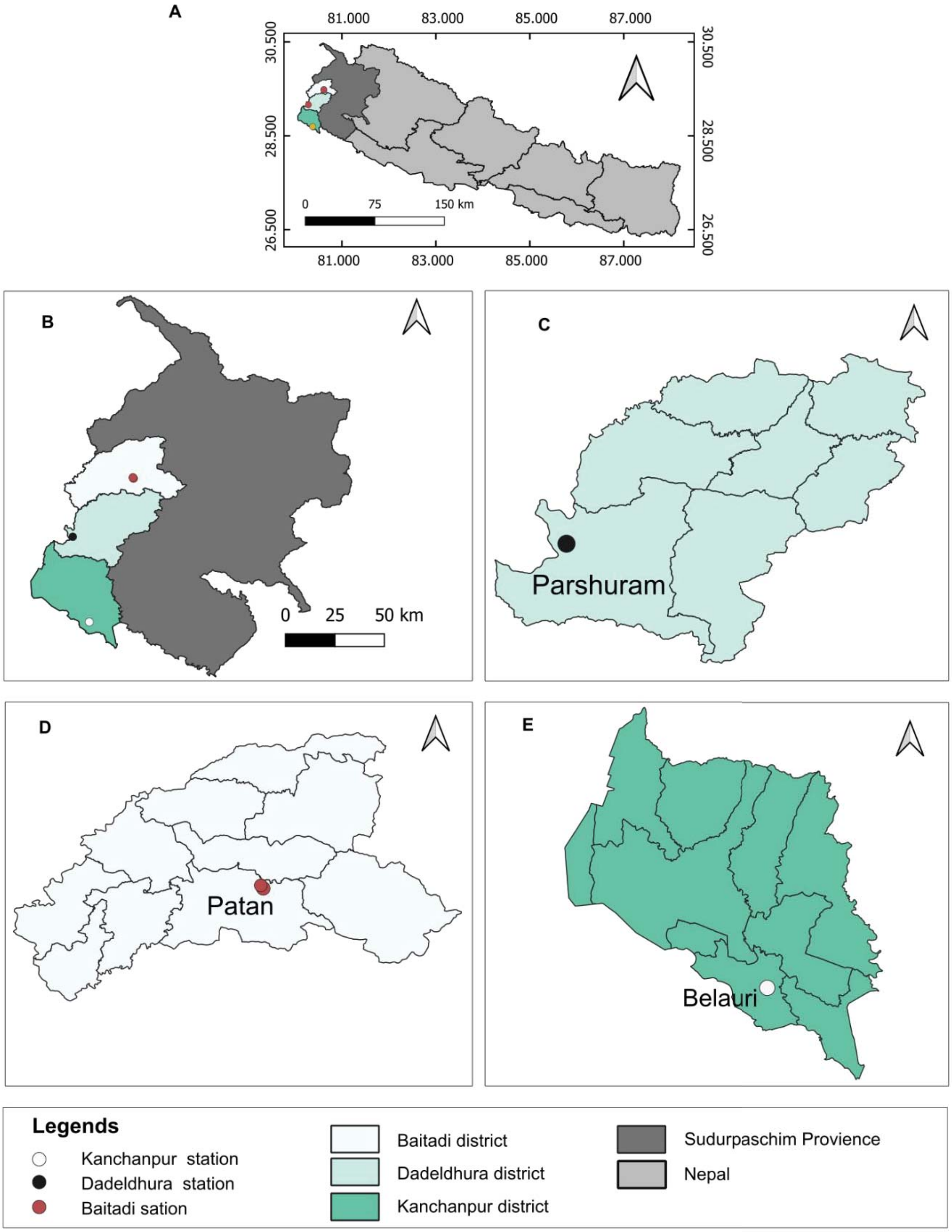

Fig. 3 Study area maps and experimental station locations. **A.** Nepal showing far-west region. **B.** Farwest Nepal. **C.** Dadeldhura district with Parshuram Municipality, point showing experimental station location. **D.** Baitadi District with point showing experimental station in Patan Municipality. **E.** Kanchanpur district with point showing the experimental station in Belauri Municipality.

2.4 Seedling preparation

Nursery beds were prepared for seedling preparation using traditional methods. The soil was tilled with the help of oxen, ensuring proper aeration. Compost manure was added to enrich the soil, as commonly practiced in field cultivation by local farmers. The seedbeds were carefully prepared by creating muddy soil with water, forming small puddles. The seeds, soaked in water and then sown in the nursery beds. Adequate water was applied to maintain the required moisture levels in the nursery beds. The sowing of seeds occurred on the 15th of Baishak, 2079 B.S. (April 28th, 2022) in Baitadi, but in Dadeldhura and Kanchanpur, the sowing took place on the 15th of Jesth, 2079 B.S. (May 29th, 2022). The selected timing aimed to ensure favorable growing conditions for the seedlings.

2.5 Tunnel preparation

For the experiment, tunnels were prepared to provide a controlled environment for the study at each experimental station. The tunnels served as water shades and facilitated the effective application of drought treatment. The tunnels were constructed using plastic water shade material supported by bamboo frames. The roof of each tunnel was covered with polythene, readily available in the market. This construction ensured that the experimental plots were shielded from rainfall, creating a controlled environment essential for conducting the different level of water treatment experiments. The use of these tunnels contributed to the precision and reliability of the study, enabling us to observe the specific responses of the plant varieties to the imposed drought conditions (Fig: 4).

2.6 Plot preparation and experimental design

For each variety three treatments were given, named as (i) control,(ii) intermittent irrigation (intermittent drought) and (iii) no irrigation (complete drought). For each treatment five replicates were conducted. For each replication 1.5 x 2 m plots were used. Altogether, there were 180 plots (12 Varieties x 3 treatments x 5 replications). The arrangements of the plots were arranged by using randomized complete block design (RCBD).

2.7 Seedling transplantation:

The transplantation of seedlings was done in the 4th of Ashad (18th June, 2022) in Baitadi, the 9th of Ashad (23th June, 2022) in Kanchanpur, and the 12th of Ashad (26th June, 2022) in Dadeldhura. During the transplantation process, 3 seedlings were planted at once for all the different rice varieties. However, for the landraces 'Shanti', a single seedling was planted.

2.8 Treatments and moisture content in plot

For a period of two weeks after the seedling transplantation, all plots were consistently irrigated. Subsequently, water treatments were applied based on the specific experimental conditions. In the control treatments, a continuous water supply was maintained, ensuring adequate irrigation. In contrast, for the intermittent irrigation (intermittent drought) treatments, watering was stopped, and re-irrigation occurred when approximately 50% of plant wilting was observed. This process of partial irrigation and wilting observation was repeated several times. In the complete drought treatments, no water was supplied after two weeks of seedling transplantation, resulting in no irrigation during the study period. The moisture content for in control plot is more than 50%, and for intermittent is around 50 % and for drought is less than 35 % (Table 3).

2.9 Morpho-agronomic parameters

2.9.1 Hill height measurement:

Hill height was measured by using a measuring tape, from the bottom of the ground to the highest flag leaf or panicle (whatever is long) of that hill. At least 25 % of plants were sampled. The hill height was measured at the time of harvesting.

2.9.2 Root length:

Root length measurements were carried out in the field by uprooting the plants using a shovel and cleaning them to remove any attached mud. Using a scale, the root length was then accurately measured, enabling a comprehensive assessment of the root system's development.

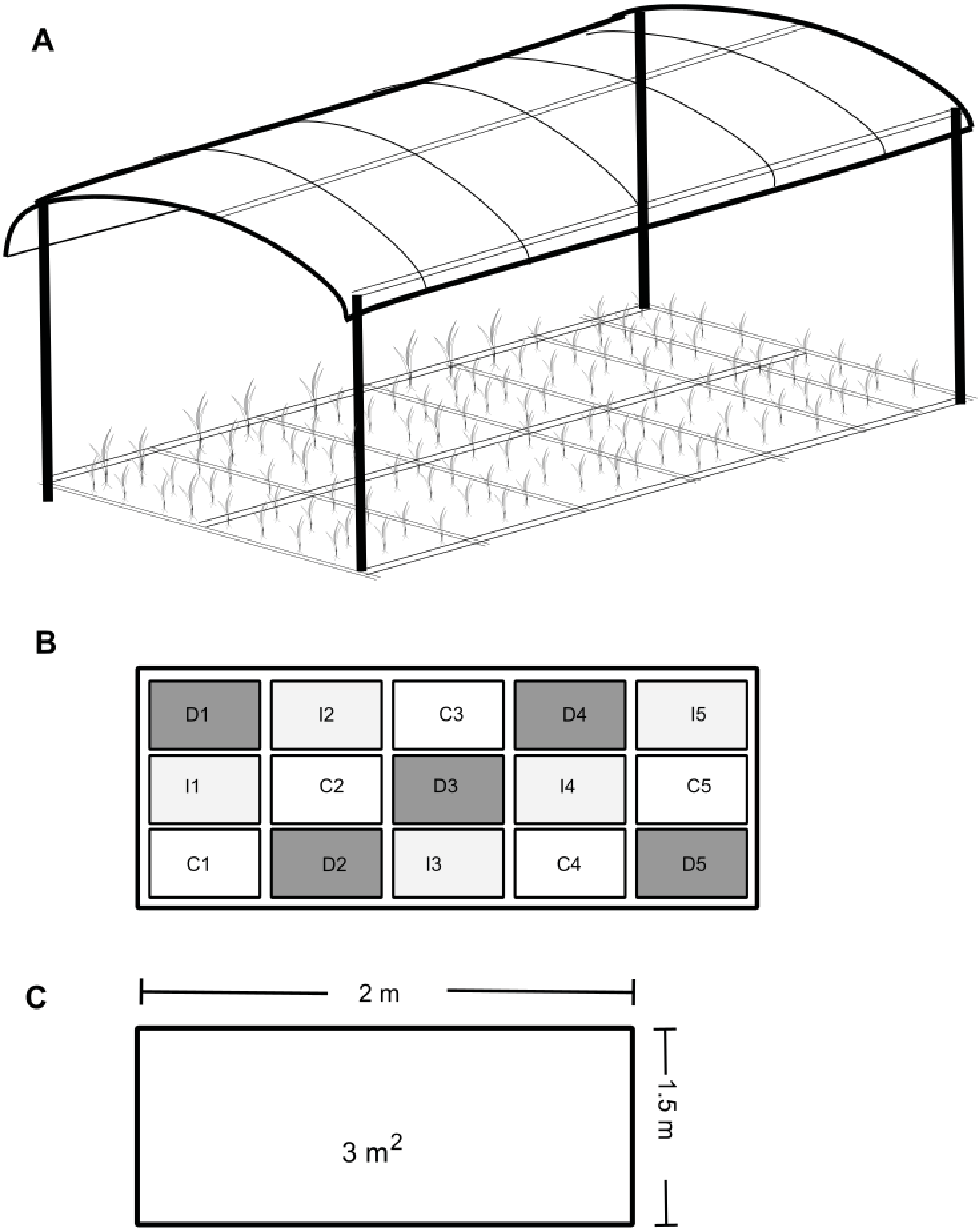

Fig. 4 Experimental design. **A.** Schematic representation of the experimental design inside the watershade; **B.** Random complete block arrangement of plots for one variety (letters C,I and D represents Control, intermittent drought and complete drought treatment respectively and the letters 1 to 5 represents the replication plots); **C.** skemmatic representation of single experimental plots (the total area of the plot is 3 m^{2-})

3.8.3 Shoot /root fresh and dry weight.

Shoot and root fresh weight measurements were conducted immediately after harvesting the plants in the field. For shoot weight measurements, 75 tillers were selected for each replication, ensuring representative data. Likewise, for root weight measurements, 25 hills were chosen, which constituted 25% of the total plants for each plot.

To determine the dry weight, the harvested shoot and root samples were transported to the laboratory, where they were dried using hot air oven at 80 °C until a constant weight was achieved. By conducting both fresh and dry weight measurements, the study captured the changes in moisture content of the shoot and root systems. The moisture percentage was calculated by using the following equation.

$$\text{Moisture percentage} = \frac{Fresh\ weight - Dry\ weight}{Fresh\ weight}$$

3.8.4 Panicle length, grain number and grain weight.

Panicles were carefully cut from the base, and their length was precisely measured by using scale ruler. Additionally, the number of grains per panicle was recorded, distinguishing between filled and non-filled grains. To determine grain weight, a sample of 1000 grains was taken from each replication and their weight was measured accurately. The yield of rice (tons per hectare) was calculated by using a modified formula given by Kandel et al (2020). The equation is given below:

$$\text{Yield (t/ha)} = \frac{Weigth\ of\ sampled\ grains \times average\ no\ of\ tillers \times total\ number\ of\ plants\ in\ plot \times 1000}{no.\ of\ sampled\ tiller \times area\ of\ plot \times 100 \times 1000}$$

2.10 Biochemical analysis

For biochemical analysis leaf sample was used. Sampling of the leaf was done during the frequent field visit held in between September, 2022. The leaf sampled was collected from each plot.

2.10.1 Chlorophyll

The measurement of chlorophyll a, chlorophyll b, carotenoid, and total chlorophyll was conducted following the protocol described by Bajracharya (1999). The chlorphyll content was measured after the emergence of the panicles.

Leaf samples were collected from each plot and immediately transported to the laboratory in an ice box to maintain their freshness. In the laboratory, 500 mg of leaf material was carefully selected and cut into small pieces, which were then transferred to a clean mortar. The leaf material was ground for approximately 5 minutes using 80% acetone as the extraction solvent.

After grinding, the resulting mixture was filtered through filter paper to remove any solid debris, thus obtaining a 50 ml volume of acetone extract. The absorbance of the extract was measured at three different wavelengths: 663 nm, 645 nm, and 440 nm. These measurements were taken using a spectrophotometer.

Based on the obtained absorbance values, the concentrations of chlorophyll a, chlorophyll b, and carotenoids were calculated using established following equations:

$$Chlorophyll\ a = 9.78\ (A663) - 0.99(A645)$$
$$Chlorophyll\ b = 21.4\ (A645) - 4.65(A663)$$
$$Total\ chlorophyll = Chlorophyll\ a + Chlorophyll\ b$$
$$Carotenoid = 4.69(A440) - 0.268(20.2(\text{A645}) + 8.02(\text{A663}))$$

Where, A663 = Absorption at 663 nm

A645= Absorption at 645 nm

A440 = Absorption at 440 nm

2.10.2 Catalase

Catalase enzyme activity was estimated using the method described by Aebi (1984). Here, 0.1 g of leaf sample was blended with ice-cold phosphate buffer using a mortar and pestle. The homogenate was then centrifuged at 11,180 x g for 10 minutes at 4°C to obtain the supernatant.

A spectrophotometer was set at 240 nm and calibrated using a mixture of 2 mL of phosphate buffer and 1 mL of 30 mM hydrogen peroxide as a blank. In the experimental cuvette, 1 mL of phosphate buffer was mixed with 1 mL of the diluted sample. To initiate the assay, 1 mL of 30 mM hydrogen peroxide was added to the cuvette and quickly placed in the spectrophotometer to measure the initial absorbance. The decrease in absorbance was monitored with a recorder for 3 minutes at 30-second intervals.

Unit/min/gram FW = (A0 - A180) * Vt * Ɛ240 / (d * Vs * Ct * 0.001),

Where,

(A0 - A180) is the difference between the initial and final absorbance,

Vt is the total volume of the reaction,

Ɛ240 is the molar extinction coefficient for hydrogen peroxide at

OD240, d is the optical path length of the cuvette,

Vs is the volume of the sample,

Ct is the total protein concentration in the sample, and

0.001 is the absorbance change caused by 1 U of enzyme per min at 240 nm OD.

This method was performed in triplicate for each sample.

2.11 Drought indices

Several drought indices was calculated to find the drought tolerance ability of the rice varieties the following equations were used to calculate the drought tolerant indices:

Mean Productivity (MP) = $\frac{Yc+Yd}{2}$ (Hossain et al., 1990)

Geometric mean productivity (GMP) = $\sqrt{Yc+Yd}$ (Fernandez, 1992)

Yield index (YI) = $\frac{Yd}{YDs}$ (Gavuzzi et al., 1997)

Stress tolerance index (STI) = $\frac{Yc+Yd}{Ys2}$ (Fernandez, 1992)

Drought resistance index (DRI) = $\frac{Yd\times(\frac{Yd}{Yc})}{Ys}$ (Lan et al., 1990)

Where,

Yc = yield of test variety in control treatment

Yd = Yeid of test variety in drought treatment.

YDs= Average yield of all the varieties in drought treatment.

Ys= Average yield of all the varieties in control treatment.

2.12 Statistical analysis

Raw data were entered in Excel 2013. Then, data from Excel 2013 was analyzed in RStudio [RStudio Team (2023). Retrieved from https://www.R-project.org/] using the *dplyr* package to calculate the mean and standard deviation. Shapiro-Wilk test was done to check the normality of the data and levene's test was done to check the homogeneity of variance. One-way ANOVA was used to assess the treatment effects in each variety, followed by Tukey HSD for variation comparison between treatments. Three-way ANOVA was performed to compare the impact of location, variety, and treatments on each parameter, and Tukey test was applied for post hoc analysis.

Drought indices were computed using specific formulae, and their correlations among themselves were examined to understand their role in defining drought tolerance in rice.

Furthermore, an AMMI2 plot was generated from varietal and environmental data using the *Metan* package to visualize overall varietal and environmental responses. Graphs were prepared by using *ggplot2* package. The final illustrations were produced using Inkscape [Inkscape Project. (2020). Retrieved from https://inkscape.org] to present the results in a clear way.

3. RESULTS

3.1 Vegetative characters of rice

3.1.1 Number of tillers per hill

Number of tillers per hill in different varieties under different treatments were measured. It is found that varieties from Kanchanpur displayed higher number of tiller, whereas those from Baitadi exhibited comparatively lower counts. Importantly, the Drought treatment led to a significant decrease in tiller numbers across all varieties, except for Jhumke from Baitadi. Among the studied varieties, Lalchand has the highest tiller count of 10.85 ± 1.71, while Chamade showed the lowest count at 2.99 ± 1.09 per hill. (Fig. 5)

3.1.2 Hill height

The hill height varies with location, variety and treatment (Table 3). In Baitadi, the Chamade variety exhibited the tallest hill height (112.74 ± 49.77 cm), while the Jhumke variety had the shortest hill height (63.58 ± 10.41 cm). Similarly, within Dadeldhura, the Jhini variety demonstrated the highest hill height (131.64 ± 14.90 cm), whereas the Shanti variety had the lowest (89.35 ± 9.36 cm). In Kanchanpur, the Sauthyari variety displayed the greatest hill height (103.93 ± 9.32 cm), and the Ghiupuri variety had the shortest (90.85 ± 7.71 cm). The drought treatments significantly reduced hill height in most varieties, except for Shanti, where no significant variation was observed. Interestingly, the Ratimarso and Temase varieties responded to the drought by increasing their hill height. (Fig. 6)

Table 3 Three-Way ANOVA result for hill height: Effects of treatment, variety, and location

Factors	Df	Sum of squares	Mean square	F value	P value	
Location	2	1281987	640993	61.549	< 0.001	***
Variety	9	846816	94091	9.035	< 0.001	***
Treatment	2	26882	13441	1.291	0.05	*
Location x Treatment	4	37358	9340	0.897	0.465	
Variety x Treatment	18	189436	10524	1.011	0.443	
Residuals	7989	83200168	10414			

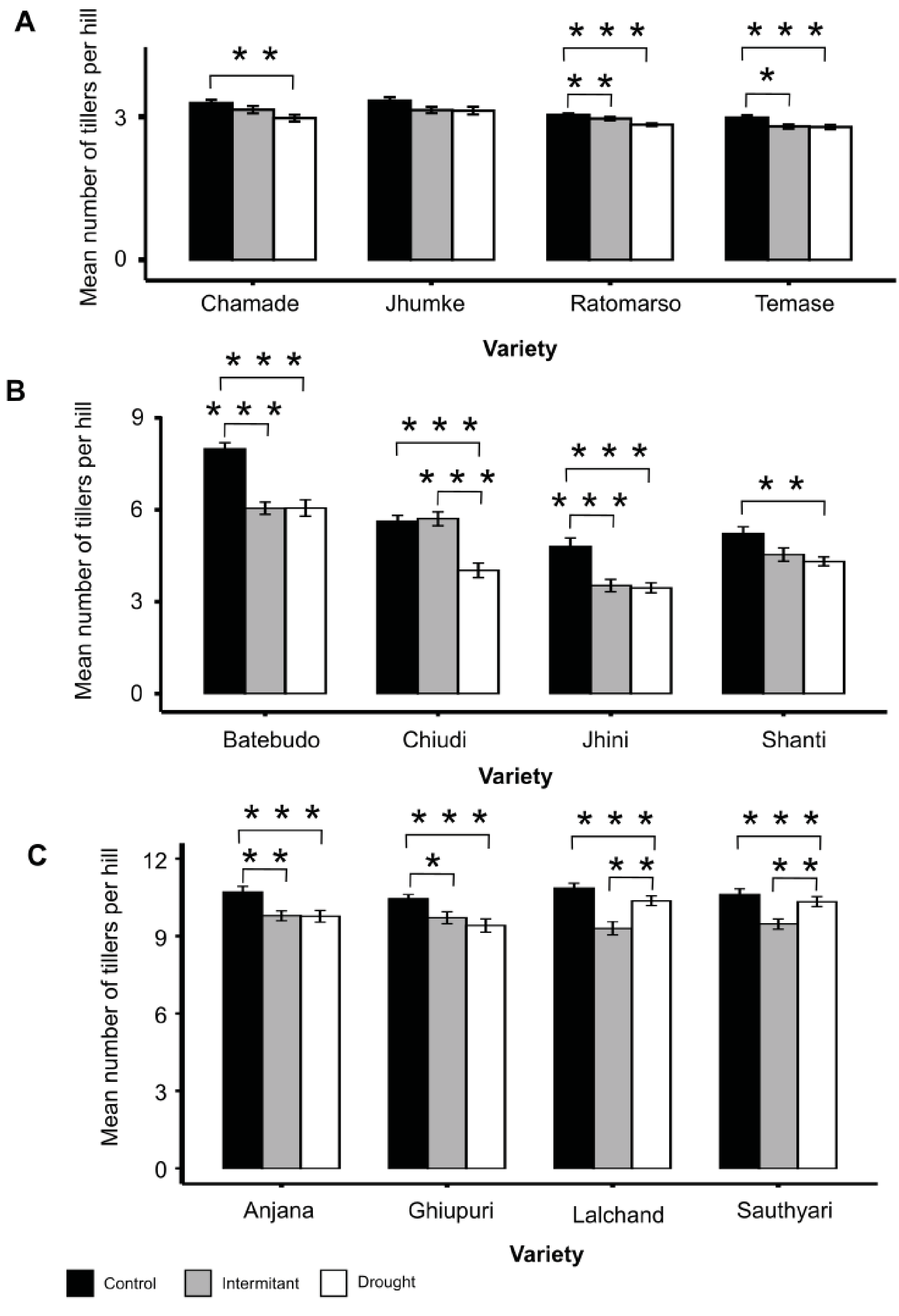

Fig. 5 Number of tiller per hills. **A.** Baitadi **B.** Dadeldhura **C.** Kanchanpur. Bar indicates mean values with standard errors (n=25). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

3.1.3 Root length

The root length for each variety in each treatment were measured. The result of three-way ANOVA for three factors location, variety and treatments reveals that there is variation in the mean root length across treatment, variety and location (Table 4)

The average root length with standard deviation is listed in the shown in bar graph (Fig. 7). In Baitadi, Among the studied varieties, Chamade exhibited the shortest root lengths, with values of 8.21 ± 2.18 cm in the drought treatment, 8.64 ± 2.34 cm in the intermittent treatment, and 9.76 ± 2.39 cm in the control treatment (Fig: 7).On the other hand, Ratomarso demonstrated the longest root lengths, measuring 10.31 ± 1.90 cm in the drought treatment, 11.23 ± 2.65 cm in the intermittent treatment, and 12.22 ± 2.67 cm in the control treatment (Fig. 7). In Dadeldhura, Batebudo's root length remained consistent across treatments. Chiudi showed increased root length in drought.The root length of Jhumke and Shanti were unaffected by treatments. (Fig. 7)

Table 4 Three-Way ANOVA for root length: Effects of treatment, variety, and location

Factors	Df	Sum of squares	Mean square	F value	P value	
Location	2	15802	7901	1406.67	< 0.001	***
Variety	2	612	306	54.51	< 0.001	***
Treatment	9	2207	245	43.66	< 0.001	***
Location x Treatment	4	624	156	27.79	< 0.001	***
Variety x Treatment	18	357	20	3.54	< 0.001	***
Residuals	3144	17659	6			

3.1.4 Root weight

The variability in root fresh weight, dry weight, and moisture percentage was shown in Fig. 8. among the varieties, Jumke and Lalchand exhibited higher root fresh weight, while Chamade and ghiupuri displayed the lowest (Fig. 8). Regarding root moisture percentage, the drought treatment significantly affected only the Chamade variety, with no notable impact observed in other varieties.

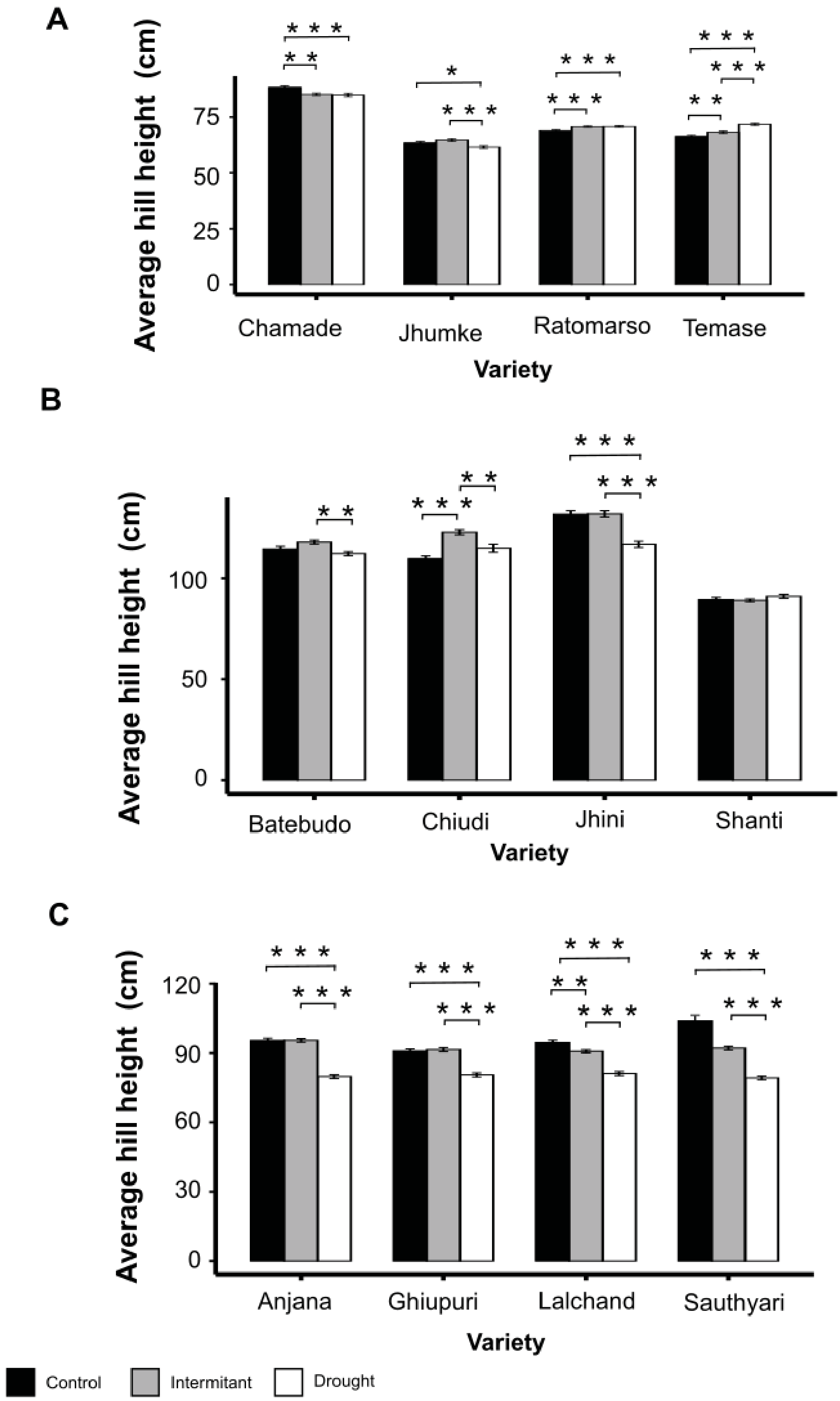

Fig. 6 Hill height in cm. **A.** Hill height of variety from Baitadi district; **B.** hill height for Dadeldhura district; **C.** hill height for Kanchanpur district Bar indicates mean values with standard errors (n=25). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

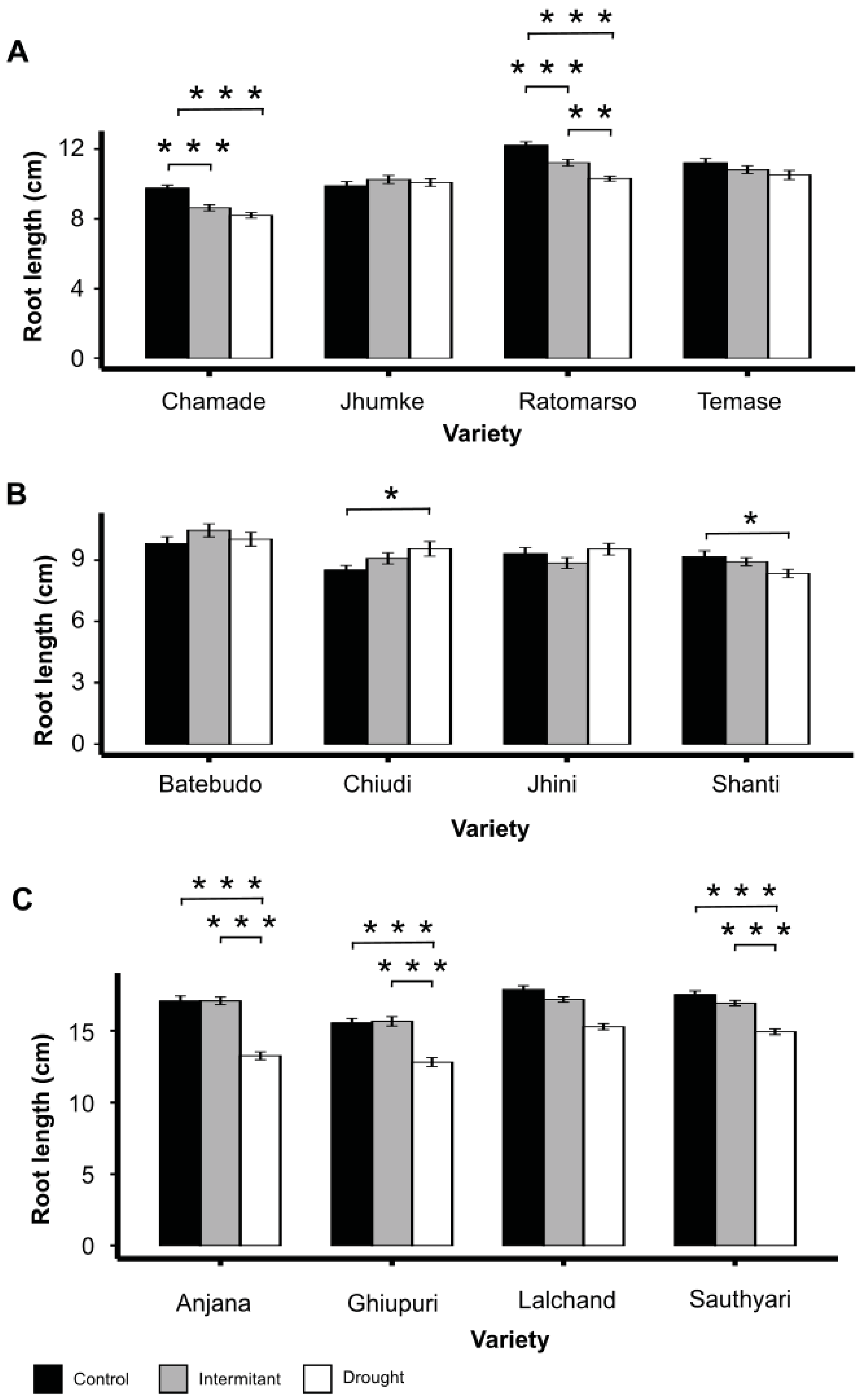

Fig. 7 Root length; **A.** Baitadi **B.** Dadeldhura. **C.** Kanchanpur. Bar indicates mean values with standard errors (n=25). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety

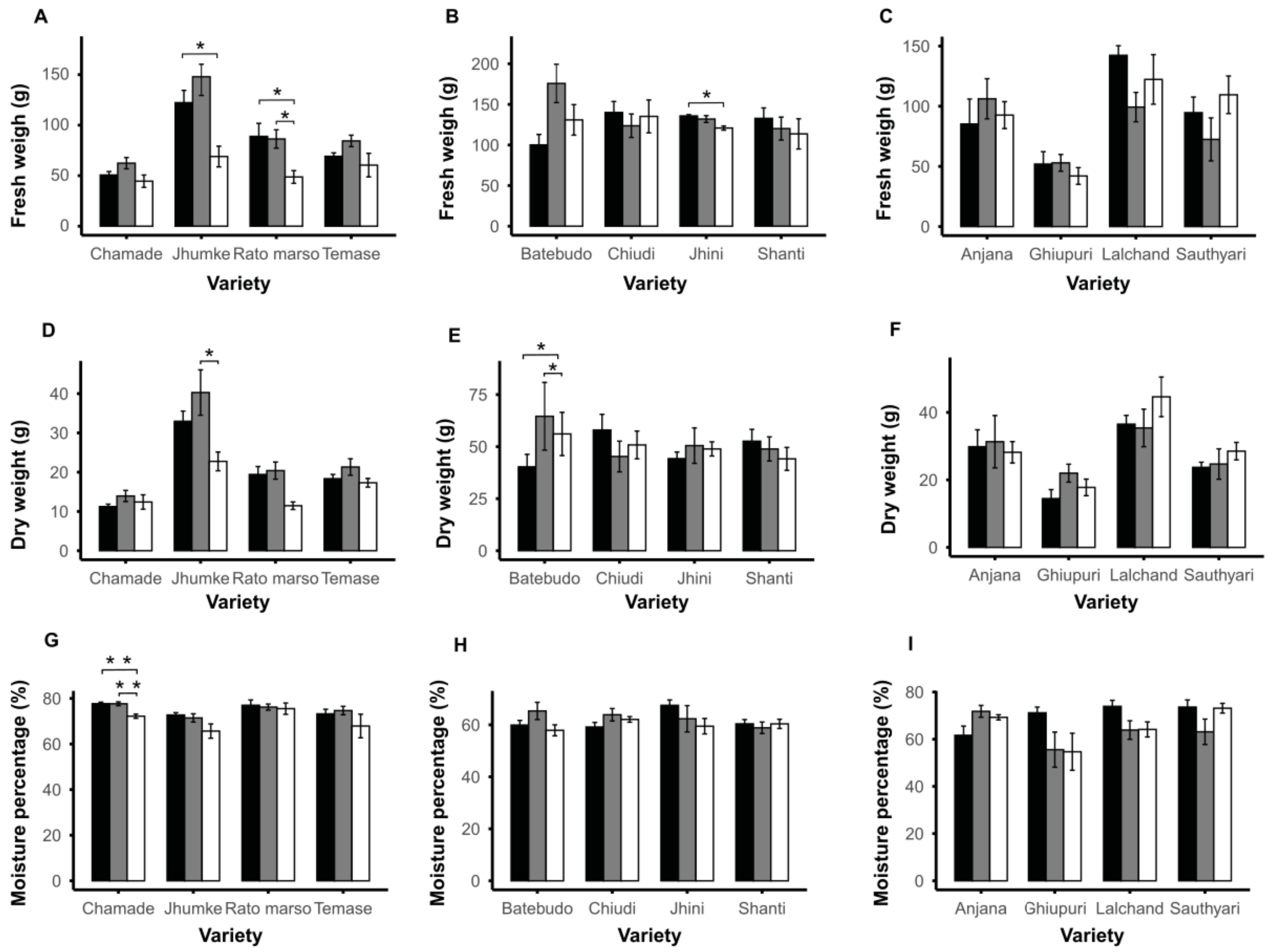

Fig. 8 Root fresh weight, root dry weight, and moisture percentage along Varieties; **A-C.** Root fresh weight **A.** Baitadi. **B.** Dadeldhura. **C.** Kanchanpur. **D-F.** Root dry weight. **D.** Baitadi. **E.** Dadeldhura. **F.** Kanchanpur.**G-I.** Root fresh weight. **G.** Baitadi. **H.** Dadeldhura. **I.** Kanchanpur. Bar indicates mean values with standard errors (n=5). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety

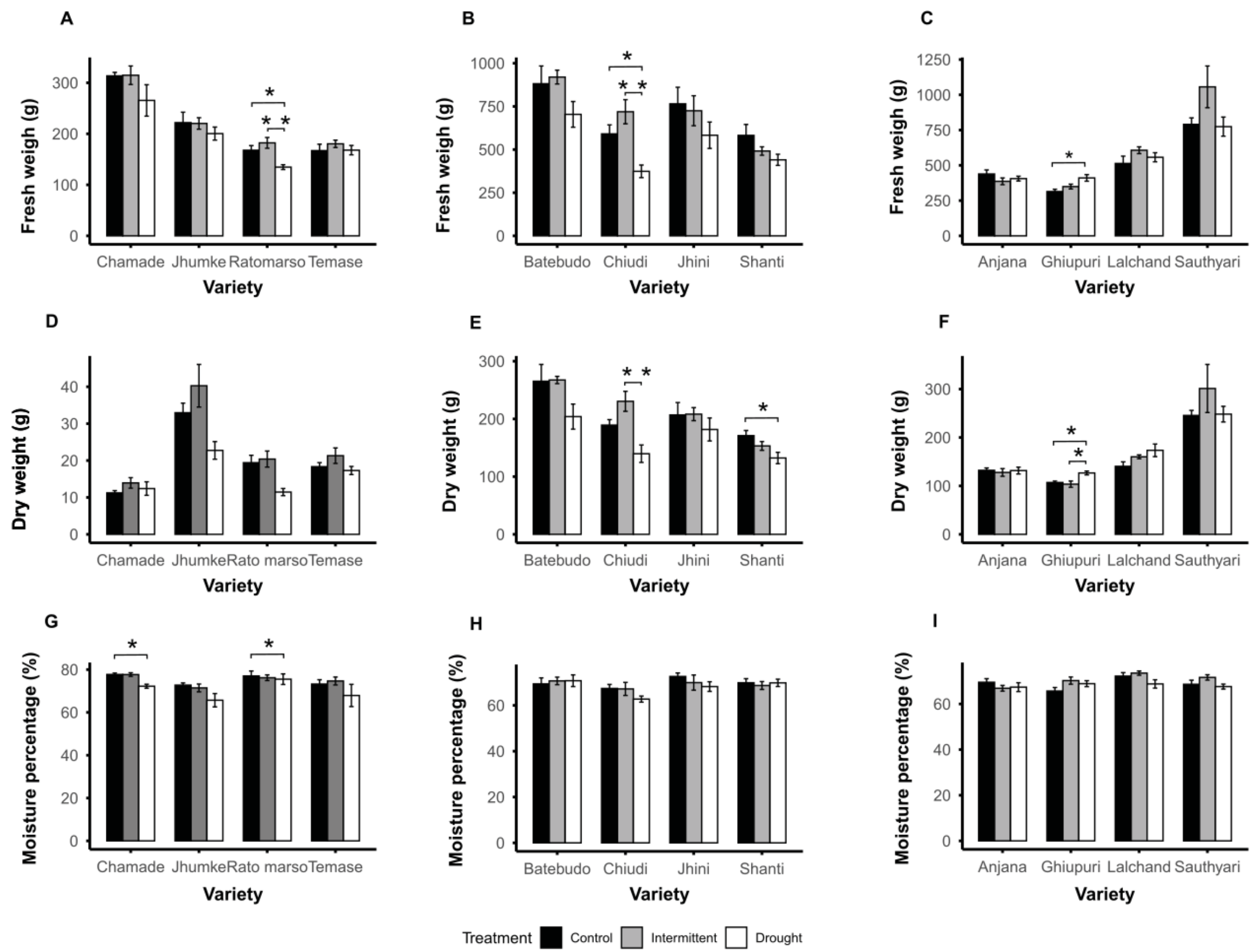

Fig. 9 Shoot fresh weight, shoot dry weight, and moisture percentage along varieties; **A-C.** Shoot fresh weight. **A.** Baitadi. **B.** Dadeldhura. **C.** Kanchanpur. **D-F.** shoot dry weight . **D.** Baitadi. **E.** Dadeldhura. **F.** Kanchanpur.**G-I.** Shoot fresh weight. **G.** Baitadi. **H.** Dadeldhura. **I.** Kanchanpur.Bar indicates mean values with standard errors (n=5) The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

3.1.5 Shoot weight

Variation of shoot fresh weight, dry weight, and moisture percentage was shown in Fig. 9. Notably, Sauthyari and Batebudo exhibited the highest shoot fresh weight, while Ghiupuri displayed the lowest. Across most varieties, the drought treatment did not significantly impact shoot fresh weight. However, significant reduction in shoot fresh weight was observed in some varieties like Ratomarso and Chiudi. Ghiupuri showed increased shoot fresh weight in response to drought. Concerning moisture percentage, Chamade and Ratomarso varieties experienced notable reduction in shoot fresh-weight due to the drought treatment (Fig. 9). While in terms of dry weight, reduction in shanti and Chiudi is seen but increase in Ghiupuri is observed.

3.2 Reproductive characters of rice

3.2.1 Panicle length

The three-way ANOVA analysis on panicle length demonstrated statistically significant effects of location, treatment and variety ($p < 0.001$ (Table 6). Panicle lengths varied across water conditions in each location. In Kanchanpur, the variety Anjana exhibited the highest range (24.87 ± 2.71 cm to 27.77 ± 2.89 cm), while Ratomarso showed the lowest range in Baitadi (14.93 ± 2.98 cm to 15.93 ± 2.45 cm) (Fig. 10). The chamade showed consistency in panicle length in all the treatments, while for other varieties the panicle length is significantly decreased due to drought stress (Fig. 10)

Table 5 Three-Way ANOVA for panicle length: Effects of treatment, variety, and location

	Df	Sum of squares	Mean square	F value	P value	
Location	2	80314	40157	4609.495	< 0.001	***
Variety	2	3191	1595	183.114	< 0.001	***
Treatment	9	21061	2340	268.611	< 0.001	***
Location x Treatment	4	566	141	16.236	< 0.001	***
Variety x Treatment	18	1548	86	9.874	< 0.001	***
Residuals	7144	62237	9			

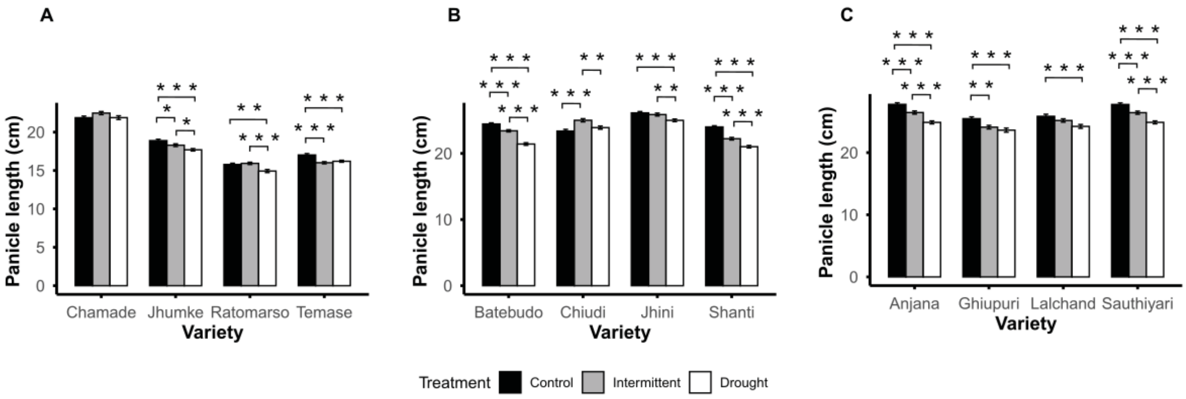

Fig. 10 Panicle length. **A.** Baitadi. **B.** Dadeldhura. **C.** Kanchanpur. Bar indicates mean values with standard errors (n=75). The symbols * represent a significant difference (* p < 0.05, ** p < 0.01, and *** p < 0.001) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

3.2.2 Grains per panicle (total grain, filled grains, non-filled grains)

The grains per panicle were measured to assess the impact of location, treatment, and variety. There was a significant main effects of location, treatment, and variety ($p < 0.001$) on non-filled grains (Table 6). Moreover, a significant interaction effect was found between location and treatment ($p < 0.001$), while the interaction effect between treatment and variety was not statistically significant ($p = 0.101$). The results demonstrate the influence of location, treatment, and variety on non-filled grains (Table 6)

Table 6 Three-Way ANOVA non-filled grains per panicle: Effects of treatment, variety, and location

	Df	Sum of squares	Mean square	F value	P value	
Location	2	4889	2444.3	25.309	< 0.001	***
Variety	2	1679	839.6	8.693	< 0.001	***
Treatment	9	7245	805	8.335	< 0.001	***
Location x Treatment	4	4098	1024.6	10.609	< 0.001	***
Variety x Treatment	18	2590	143.9	1.49	< 0.001	***
Residuals	145	14004	96.6			

The three-way ANOVA for filled grains indicated significant main effects of location ($p< 0.001$), treatment ($p< 0.001$), and variety ($p< 0.001$), as well as significant interaction effects between location and treatment ($p< 0.001$). However, the interaction effect between treatment and variety was statistically significant ($p< 0.001$) (Table 7).

Table 7 Three-Way ANOVA for filled grains per panicle: Effects of treatment, variety, and location

	Df	Sum of squares	Mean square	F value	P value	
Location	2	108616	54308	249.758	< 0.001	***
Variety	2	16900	8450	38.86	< 0.001	***
Treatment	9	54757	6084	27.98	< 0.001	***
Location x Treatment	4	21352	5338	24.549	< 0.001	***
Variety x Treatment	18	11530	641	2.946	< 0.001	***
Residuals	145	31529	217			

The three-way ANOVA analysis for the total number of grains revealed significant main effects of location, treatment, and variety ($p < 0.001$), indicating their influence on grain production. Additionally, there was a significant interaction effect between location and treatment ($p< 0.001$), suggesting a combined impact on grain count. (Table 8).

Table 8 Three-Way ANOVA for total number of grains per panicle: Effects of treatment, variety, and location

	Df	Sum of squares	Mean square	F value	P value	
Location	2	158224	79112	249.758	< 0.001	***
Variety	2	7881	3941	38.86	< 0.001	***
Treatment	9	87227	9692	27.98	< 0.001	***
Location x Treatment	4	8196	2049	24.549	< 0.001	***
Variety x Treatment	18	6096	339	2.946	< 0.001	***
Residuals	145	39549	273			

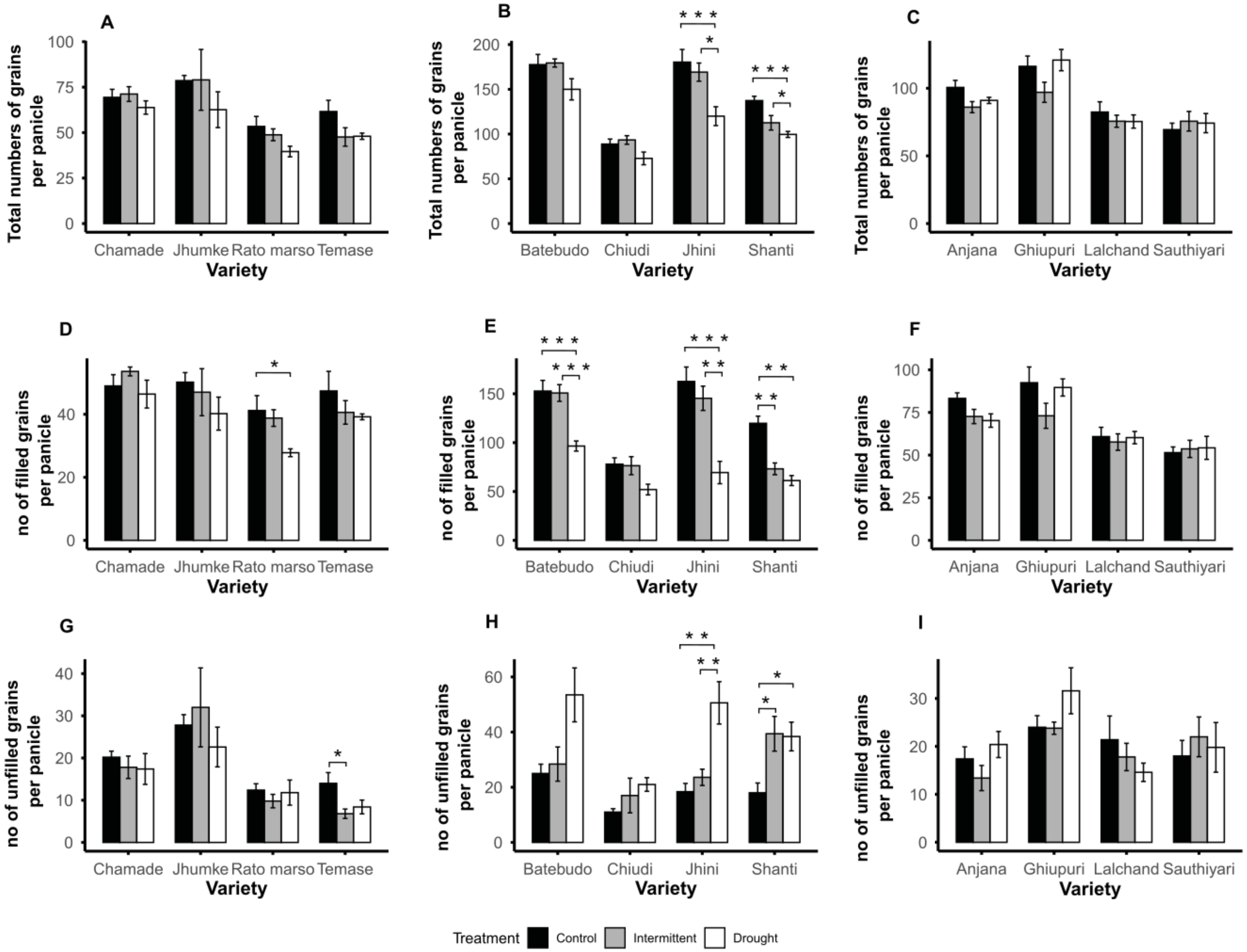

Fig: 11 Total number of grains per panicle , number of filled grains per panicle, and number of non filled grains per panicle along Varieties; **A-C.** Total number of grains per panicle. **A.** Baitadi. **B**. Dadeldhura. **C.** Kanchanpur. **D-F.** Filled grains per panicle. **D.** Baitadi. **E**. Dadeldhura. F. Kanchanpur.**G-I**. Non-filled grains per panicle. **G.** Baitadi. **H.** Dadeldhura. **I**. Kanchanpur. Bar indicates mean values with standard errors (n=5). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

In Chamade variety, total grain counts varied slightly among treatments with no significant differences observed in total grains per panicle ($p > 0.05$). Similarly in Jhumke variety, total grain counts differed (Control: 78.35±6.49, Intermittent: 79.08±37.43, Drought: 62.44±22.22), but no significant differences were found between treatments ($p > 0.05$). For Ratomarso, Drought significantly impacted grain production (12.36±3.20 total grains) compared to Control (53.44±12.50 total grains, $p = 0.0792$), while Intermittent showed no difference (41.09±10.81 total grains, $p = 0.709$). Temase exhibited similar trends with no significant among treatments (Fig. 11).

In Dadeldhura, the Batebudo and Chiudi varieties exhibited no significant impact of the treatment on the total grains per panicle. However, in the case of the Jhini and Shanti varieties, the drought treatment significantly reduced the total number of grains per panicle due to the treatment (Fig. 11). Contrastingly, in the Kanchanpur, the total number of grains per panicle did not show significant variation among the different treatments. For instance, in the Batebudo and Chiudi varieties of Dadeldhura, the total grains per panicle remained relatively stable across treatments, reflecting a potential resilience to the applied conditions. In contrast, the Jhini and Shanti varieties displayed a noticeable decrease in total grains per panicle under the drought treatment (Fig. 11).

Table 9 yield (mean ± s.d., n=5) tons per hectare.

Location	Variety	Yield (t/ha)		
		Control	**Intermittent**	**Drought**
Baitadi	**Chamade**	4.15±0.77	3.74±0.64	3.43±0.77
	Jhumke	5.42±0.93	4.30±1.64	3.74±1.41
	Ratomarso	2.95±0.69	2.41±0.32	1.62±0.22
	Temase	3.21±0.85	2.53±0.46	2.02±0.26
Dadeldhura	**Batebudo**	6.62±1.21	5.05±0.60	3.48±0.32
	Chiudi	3.57±0.61	3.56±0.61	1.60±0.33
	Jhini	3.38±0.68	2.17±0.47	1.20±0.26
	Shanti	2.88±0.48	1.79±0.27	1.39±0.39
Kanchanpur	**Anjana**	4.90±0.54	3.87±0.50	3.77±0.56
	Ghiupuri	3.39±0.54	2.71±0.46	3.23±0.26
	Lalchand	3.87±0.82	3.14±0.34	3.50±0.52
	Sauthiyari	5.67±0.70	5.22±1.10	5.37±0.74

3.2.3 Yield

Table 9 presents the mean yield values (mean ± sd) in tons per hectare for each variety under control, intermittent, and drought water regimes. The drought treatment demonstrates a distinct influence on yield, exhibiting statistical significance primarily in varieties including

Ratomarso, Temase, Batebudo, Chiudi, Jhini, Shanti, and Anjana. Conversely, in the case of Chamade, Jhumke, Ghiupuri, Lalchand, and Sauthyari varieties, there were no significant reduction in yields (Fig. 12).

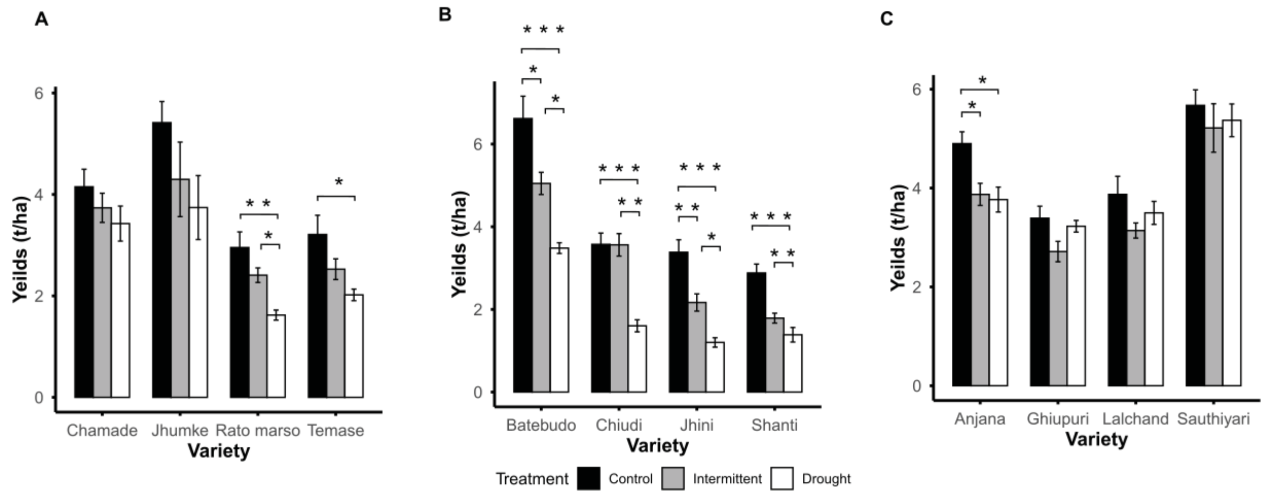

Fig. 12 Yields (t/ha). **A.** Baitadi. **B.** Dadeldhura. **C.** Kanchanpur. Bar indicates mean values with standard errors (n=5). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

3.3 Biochemical parameters

3.3.1 Chlorophyll contents

Variations in pigment levels were observed among different plant varieties during the harvesting phase in Baitadi. The range of chlorophyll a content in Baitadi within treatments extended from 0.11 to 1.06 µg/g FW, while chlorophyll b spanned from 0.12 to 0.87 µg/g FW. Carotenoid content displayed a range of 0.14 to 0.46 µg/g FW, and the total chlorophyll content exhibited a range of 0.23 to 1.87 µg/g FW. There were no substantial variations in pigment levels among the different treatments within varieties, but the Ratomarso variety exhibited significant changes in chlorophyll a, b, and total chlorophyll across the treatments. However, levels of carotenoids remained unaffected by the treatment. (Fig. 13). In Dadeldhura the pigment levels vary between varieties but there is not any significant impact of drought. Except in Batebudo where the drought has decreased the carotenoid. (Fig. 14)

In Kanchanpur also, at harvest, pigment levels varied within varieties. The chlorophyll a content ranged from 1.12 to 1.24 µg/g FW, chlorophyll b from 0.57 to 0.94 µg/g FW, carotenoids from 0.44 to 0.49 µg/g FW, and total chlorophyll content from 1.68 to 3.10 µg/g

FW. Treatments induced significant changes in Ghiupuri's chlorophyll a, b, and carotenoid, while for other variety, there is no significant impact of treatment in those pigments (Fig. 15).

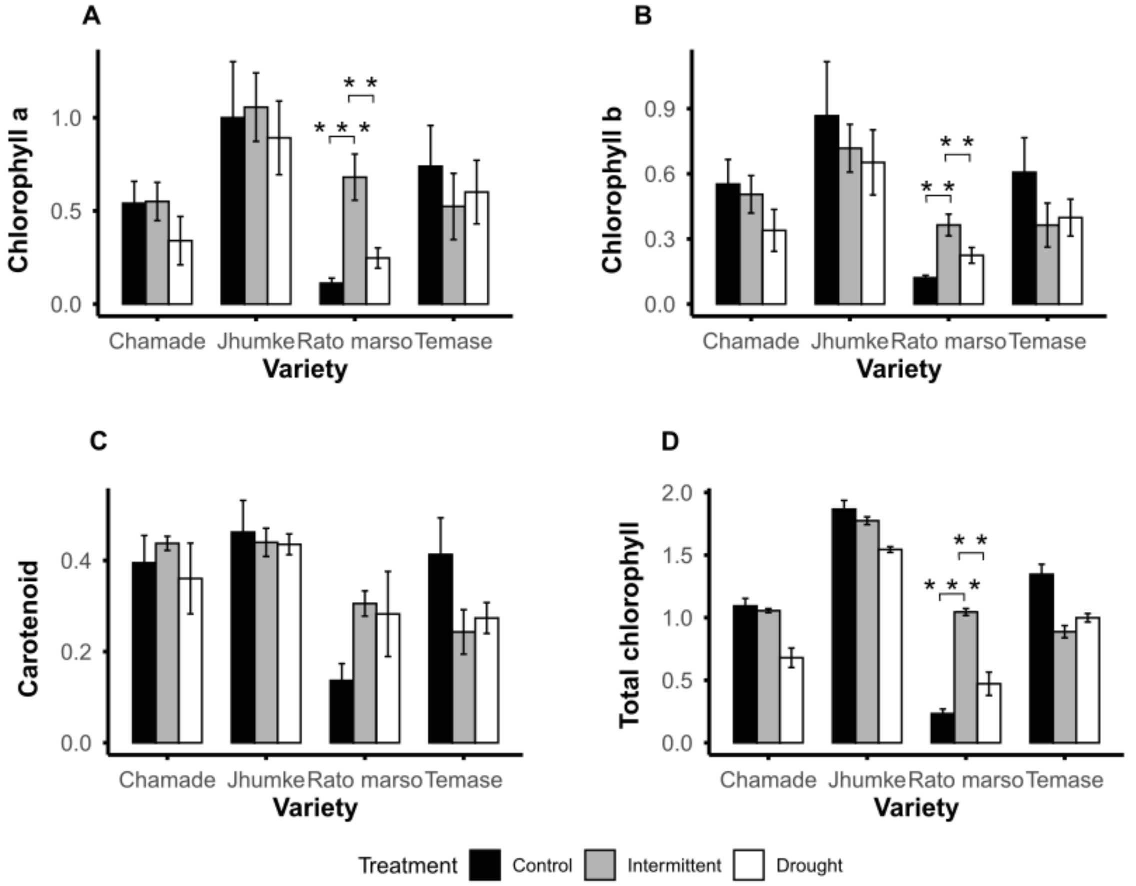

Fig. 13 Chlorophyll at the time of harvesting, Baitadi. **A.** Chlorophyll a. **B.** Chlorophyll b. **C.** Carotenoid. **D.** Total chlorophyll. Bar indicates mean values with standard errors (n=5). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

3.3.2 Catalase activity

The catalase activity was measured in units/min/fresh weight from leaf sample and shown in Fig: 21. Analysis revealed that the variety, location and treatment has significant impact in catalase activity (Table 10).

Table 10 Three-Way ANOVA for catalase activity: Effects of treatment, variety, and location

	Df	Sum of squares	Mean square	F value	P value	
Location	2	10371	5186	263.782	< 0.001	***
Variety	2	3772	419	21.317	< 0.001	***
Treatment	9	3168	1584	80.568	< 0.001	***
Location x Treatment	4	502	125	6.381	< 0.001	***
Variety x Treatment	18	434	24	1.227	0.247	
Residuals	145	2831	20			

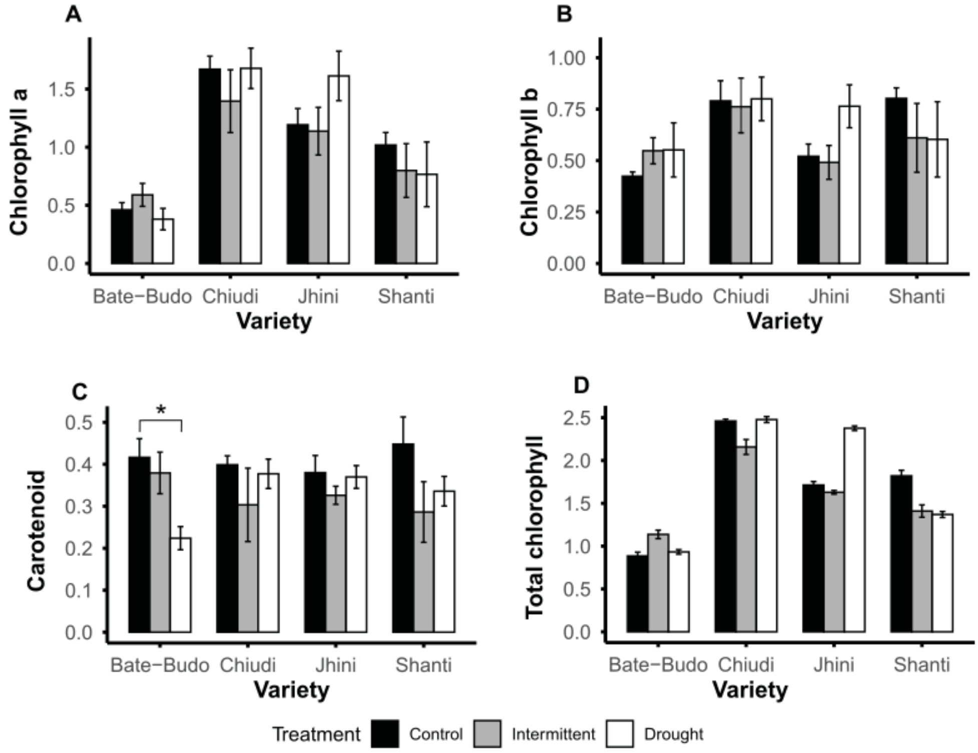

Fig. 14 Chlorophyll at the time of harvesting, Dadelhura. **A.** Chlorophyll a. **B.** Chlorophyll b. **C.** Carotenoid. **D.** Total chlorophyll. Bar indicates mean values with standard errors (n=5). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

In the Baitadi, catalase activity exhibited distinct variations across different varieties. The catalase activity ranged from 56.16±9.20 to 84.53±3.20 units/min/g FW. The highest catalase activity was observed in the Chamade variety, while the lowest was in the Temase variety. There is significant increase in the catalase activity in all the varieties across treatments (Fig. 16).

In Dadeldhura, catalase activity varied across different plant varieties. The catalase activity ranged from 54.15±2.94 to 67.05±5.59 units/min/g FW. Among the varieties, the highest catalase activity was observed in the Jhini variety, while the lowest was in the Batebudo variety. The analysis revealed that the intermittent drought has no effect on the catalase activity whereas the complete dtrought has significantly increased the catalase activity in Batebudo and jinni. However, for chiudi and shanti there is no effect of treatment in catalase activity.

In Kanchanpur, catalase activity exhibited variations across varieties. Anjana ranged from 46.70 to 58.74, Ghiupuri from 43.27 to 54.44, Lalchand from 44.70 to 62.46, and Sauthyari from 45.27 to 62.75 units/min/g FW. Drought treatment significantly increased catalase activity in Anjana (p=0.003), Ghiupuri (p=0.001), Lalchand (p<0.001), and Sauthyari (p=0.008) compared to Control. Intermittent treatment didn't yield significant differences in any variety compared to Control. However, significant differences emerged between Drought-Intermittent and Control treatment in Anjana (p=0.02), Ghiupuri (p=0.051), and Sauthyari (p=0.034) (Fig. 16).

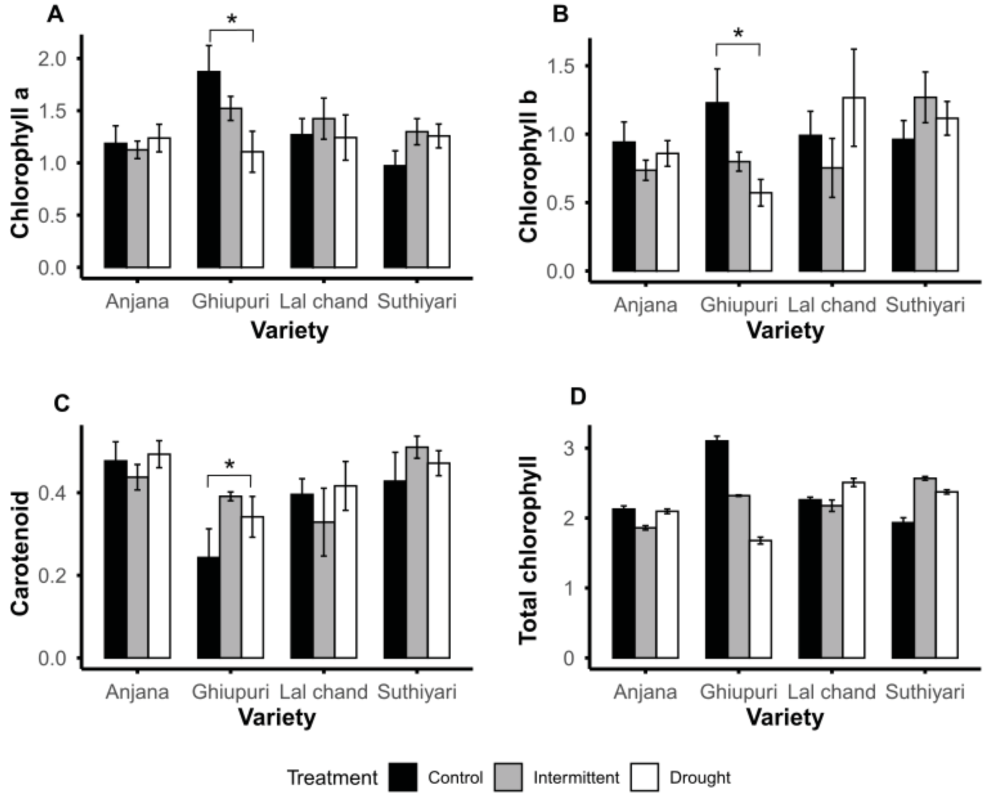

Fig. 15 Chlorophyll at the time of harvesting, Kanchanpur. **A.** Chlorophyll a. **B.** Chlorophyll b. **C.** Carotenoid. **D.** Total chlorophyll. Bar indicates mean values with standard errors (n=5). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

3.4 Analysis between measured parameters

3.4.1 Correlation between measured parameters

The correlations between different parameters in the study was analyzed. From analysis it found that root length showed a significant positive correlation with the number of tillers across all treatments. However, the root moisture content exhibited a significant negative correlation with the number of tillers per hill, indicating that as the root moisture decreased, the number of tillers increased. This negative correlation was observed in all treatments. Furthermore, the shoot moisture content showed a significant negative correlation with the number of tillers across all treatments. In other words, as the shoot moisture content decreased, the number of tillers increased. Interestingly, the yield showed a positive significant correlation with the number of tillers, suggesting that higher numbers of tillers were associated with increased yield. Moreover, it is also observed that drought treatments had a stronger and more significant correlation with both yield and the number of tillers per hill. This indicates that the impact of drought on yield and tiller production was more pronounced in the drought treatments compared to other treatments. (Fig. 17).

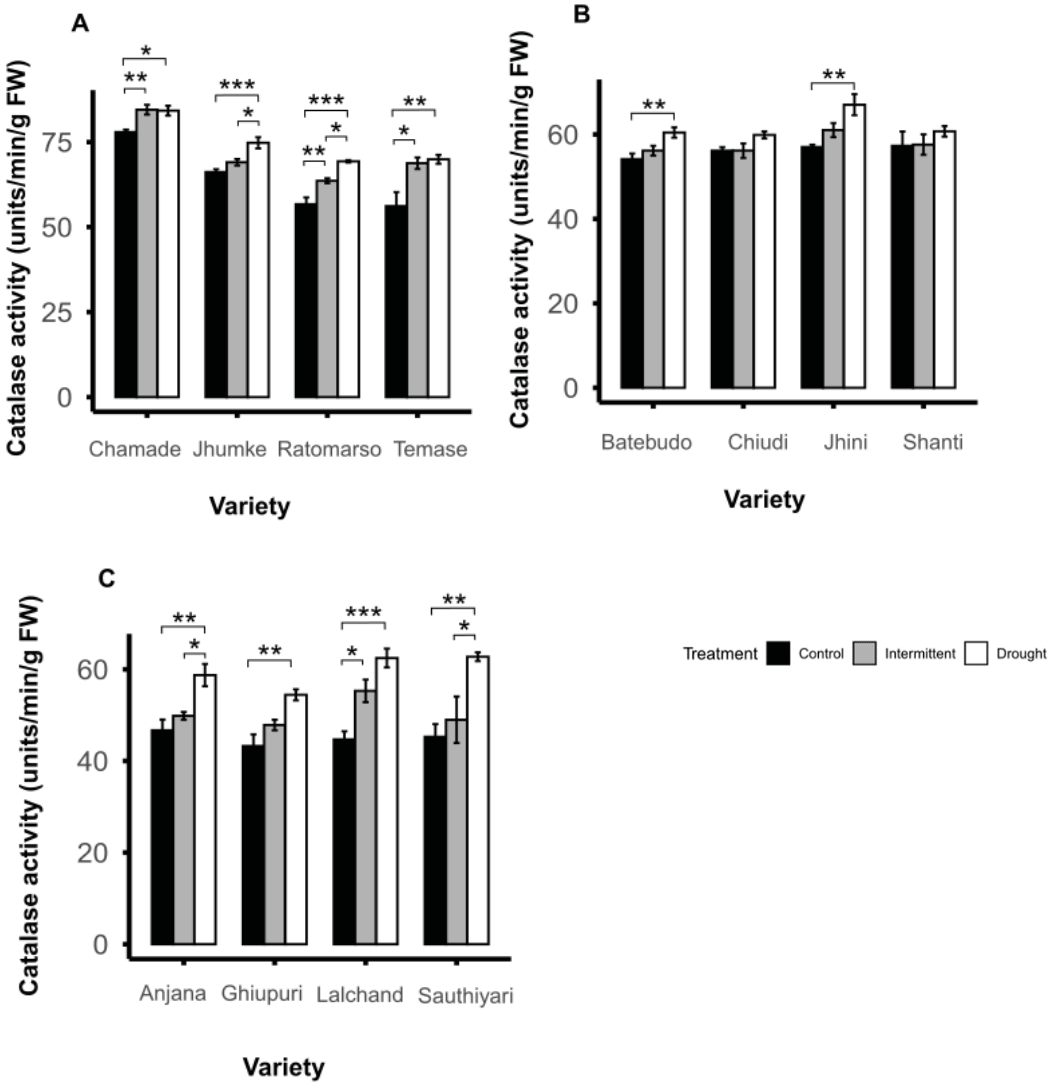

Fig. 16 Catalase activity. **A.** Baitadi. **B.** Dadeldhura. **C.** Kanchanpur. Bar indicates mean values with standard errors (n=5). The symbols * represent a significant difference (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$) as determined by Tukey's HSD test following one-way ANOVA for treatment in each variety.

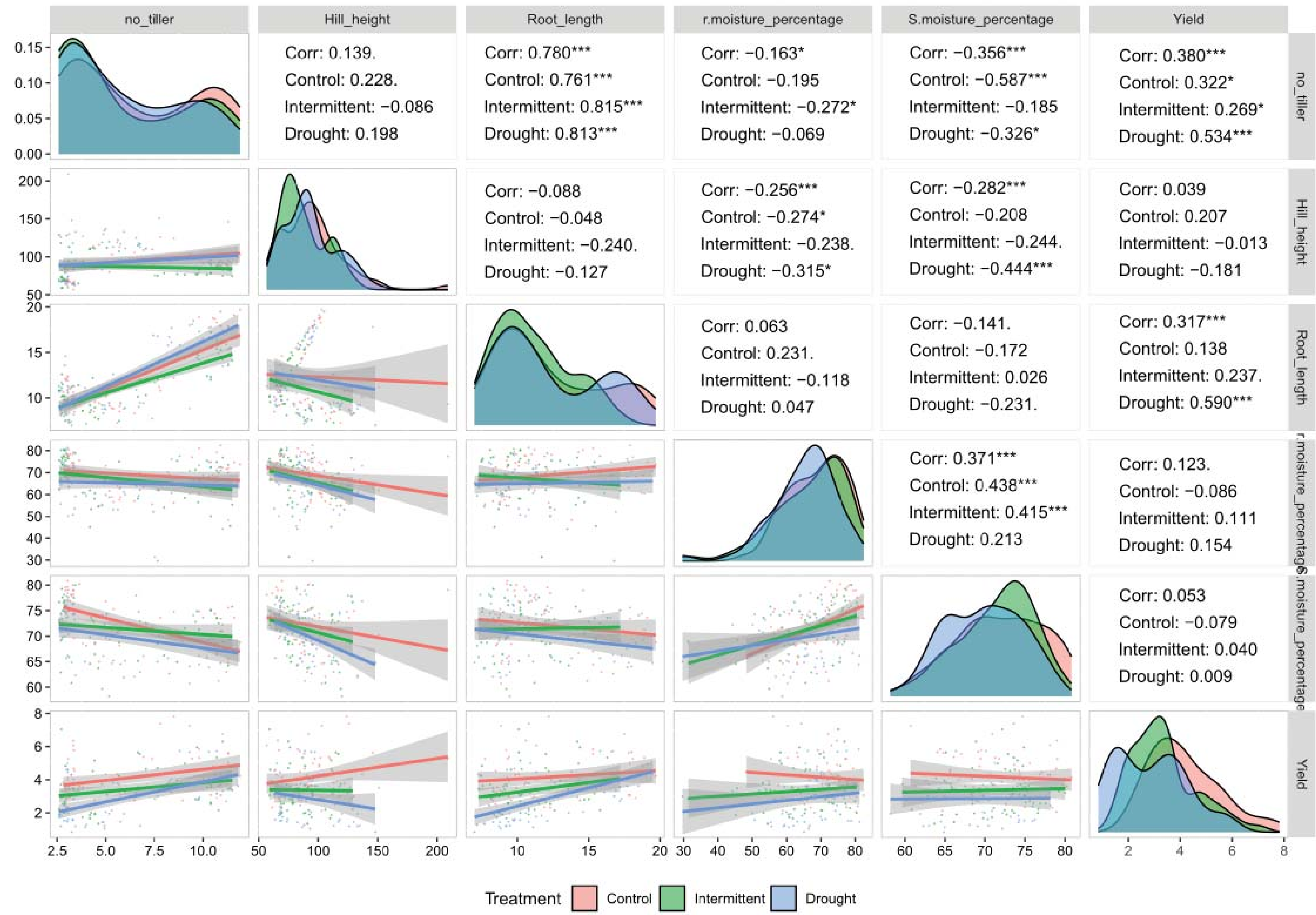

Fig. 17 Correlation between morphological parameters and yield in all treatments. The symbol * shows the significance correlation (* p<0.05, ** p<0.01 and *** p<0.001)

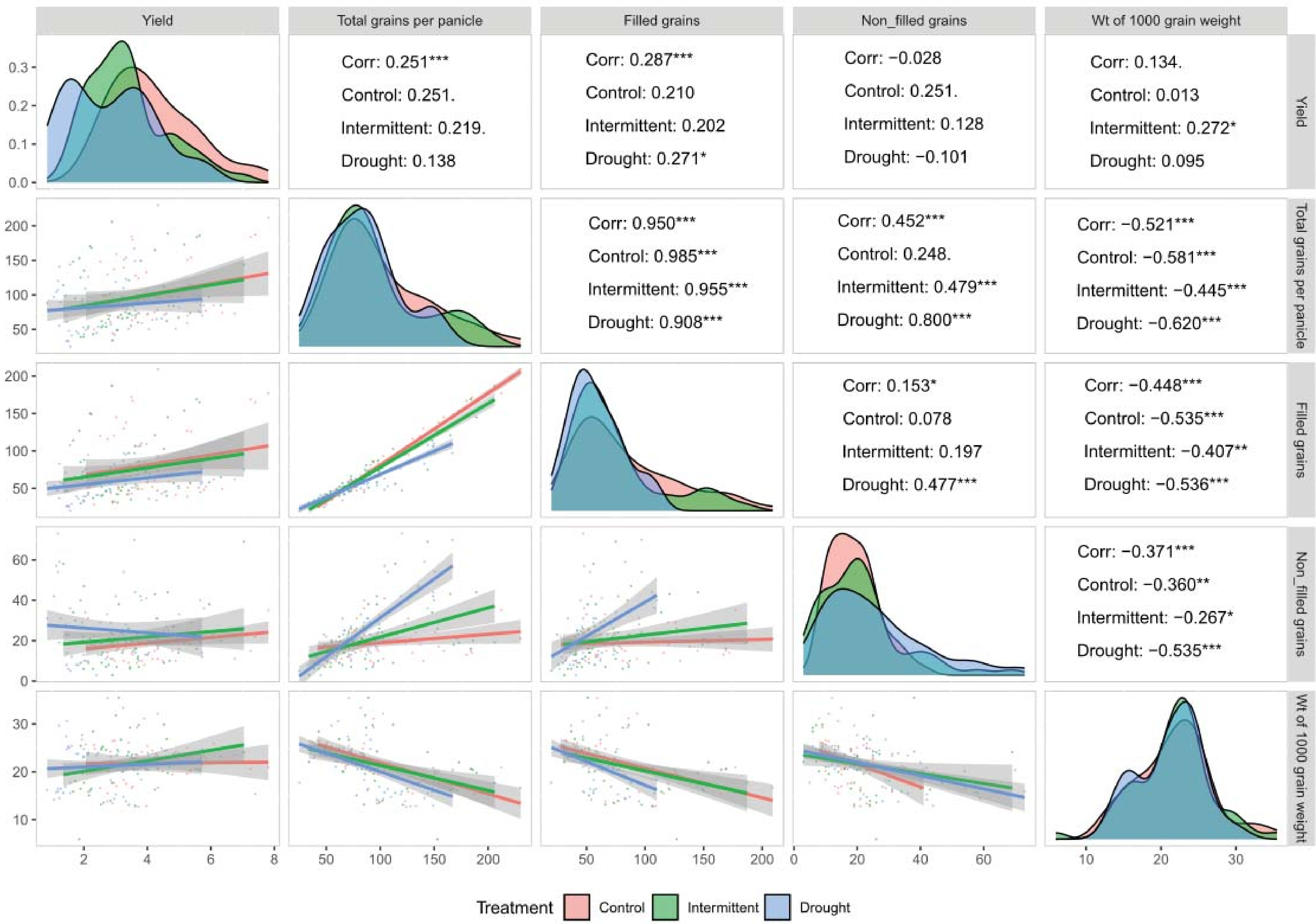

Fig. 18 correlation of yield with the reproductive characters. The symbol * shows the significance correlation (* p<0.05, ** p<0.01 and *** p<0.001

On the other hand, there is no significant correlation between root length and hill height. However, root moisture content showed a negative correlation with hill height, meaning that as hill height increased, root moisture content decreased. Root moisture content did not show any correlation with shoot moisture, and similarly, shoot moisture did not show any correlation with root length (Fig. 17).

In the context of yield, it is observed that it was positively correlated with root length, especially in the drought treatment. This suggests that in drought conditions, an increase in root length could lead to higher yields. Additionally, there is a positive correlation between shoot moisture percentage and root moisture percentage, indicating that higher shoot moisture was associated with higher root moisture. However, analysis did not reveal any significant correlation between yields and shoot moisture percentage (Fig. 17)Analysis revealed a positive correlation between yield and both the total grains per panicle and the filled grains per panicle. However, in drought treatments, the number of filled grains per panicle is a critical factor influencing yield. Specifically, a positive and significant correlation was observed between yield and the number of filled grains per panicle in drought treatments (Fig. 18)

3.4.2 Drought tolerance index

This study evaluated various drought tolerance indices to assess the performance of twelve rice varieties across three agroclimatic zones under intermittent and complete drought conditions. The indices used for evaluation included Mean productivity (MP), Geometric mean productivity (GP), Yield index (YI), Stress tolerance index (STI) and Drought resistant index (DRI). Table 11 presents the calculated drought tolerance indices for each rice variety under intermittent drought (ID) and complete drought (CD) conditions, as well as their respective values for MP, GP, and YI, STI and DRI.

Among the tested varieties in Baitadi, Chamade demonstrated moderate drought tolerance with an STI value of 0.454 under intermittent drought and 0.413 under complete drought. Jhumke displayed higher stress tolerance, recording STI values of 0.560 and 0.463 under intermittent and complete drought, respectively. Rato marso and Temase exhibited relatively lower STI values, indicating their limited ability to cope with water stress (Table 12).

In Dadeldhura, Batebudo displayed remarkable drought tolerance with an STI value of 0.672 under intermittent drought and 0.491 under complete drought. On the other hand, Chiudi exhibited a moderate STI value under both drought conditions, while Jhini and Shanti showed relatively lower STI values, suggesting their susceptibility to water scarcity (Table 11).

In Kanchanpur, Anjana displayed moderate drought tolerance, recording STI values of 0.505 under intermittent drought and 0.440 under complete drought. Ghiupuri, Lalchand, and Sauthiyari exhibited varying degrees of drought tolerance, with Sauthiyari showing the highest STI value among all varieties tested (Table 11).

Table 11 Drought tolerance indices (MP, GP, YI, STI, DTE, and DRI) for rice varieties under intermittent drought (ID) and complete drought (CD) treatments.

Location	Variety	MP		GP		YI		STI		DRI	
		ID	CD	ID	CD	ID	CD	ID	CD	ID	CD
Baidtadi	**Chamade**	3.95	3.79	3.94	3.77	1.11	1.20	0.45	0.41	17.20	17.06
	Jhumke	4.86	4.58	4.83	4.50	1.27	1.31	0.56	**0.46**	**29.70**	26.48
	Rato marso	2.68	2.29	2.67	2.19	0.71	0.57	0.31	0.23	5.08	2.70
	Temase	2.87	2.62	2.85	2.55	0.75	0.71	0.33	0.26	6.09	4.58
Dadeldhura	**Batebudo**	5.84	5.05	5.78	4.80	1.50	1.22	0.67	**0.49**	**50.04**	28.01
	Chiudi	3.57	2.59	3.56	2.39	1.06	0.56	0.41	0.30	13.41	3.19
	Jhini	2.78	2.29	2.71	2.01	0.64	0.42	0.32	0.19	4.72	1.70
	Shanti	2.34	2.14	2.27	2.00	0.53	0.49	0.27	0.18	2.73	1.94
Kanchanpur	**Anjana**	4.39	4.34	4.35	4.30	1.15	1.32	0.50	0.44	21.75	24.33
	Ghiupuri	3.05	3.31	3.03	3.31	0.80	1.13	0.35	0.34	7.38	12.36
	Lalchand	3.51	3.69	3.49	3.68	0.93	1.22	0.40	0.38	11.31	16.56
	Sauthiyari	5.45	5.52	5.44	5.52	1.55	1.88	0.63	**0.61**	**45.79**	57.12

ID= Intermittent drought, CD=Complete Drought, MP= Mean Productivity, GP=Geometric mean productivity, YI= Yield index, STI= Stress tolerance index, DTE= Drought tolerance index, DRI= Drought resistent index

3.4.2.1 Correlation between different drought indices

The correlation analysis of drought tolerance indices in rice under intermittent drought conditions has provided valuable insights into the interrelationships between various indices. The correlation matrix reveals strong positive correlations between Mean Productivity (MP) and Geometric Mean Productivity (GP) (r = 0.999), indicating a very high degree of association between these two indices. Similarly, MP and Yield Index (YI) exhibit a robust positive correlation (r = 0.982). Furthermore, YI and Stress Tolerance Index (STI) also demonstrate a high positive correlation (r = 0.982), indicating a strong association between Yield Index and Stress Tolerance Index. Moreover, DRI and GP exhibit a notable positive correlation (r = 0.977), indicating a potential link between Drought Resistant Index and Geometric Mean Productivity. This suggests that rice cultivars with higher Drought Resistant Index may also possess better Geometric Mean Productivity, which could be a valuable trait for drought-prone regions (Fig. 19).

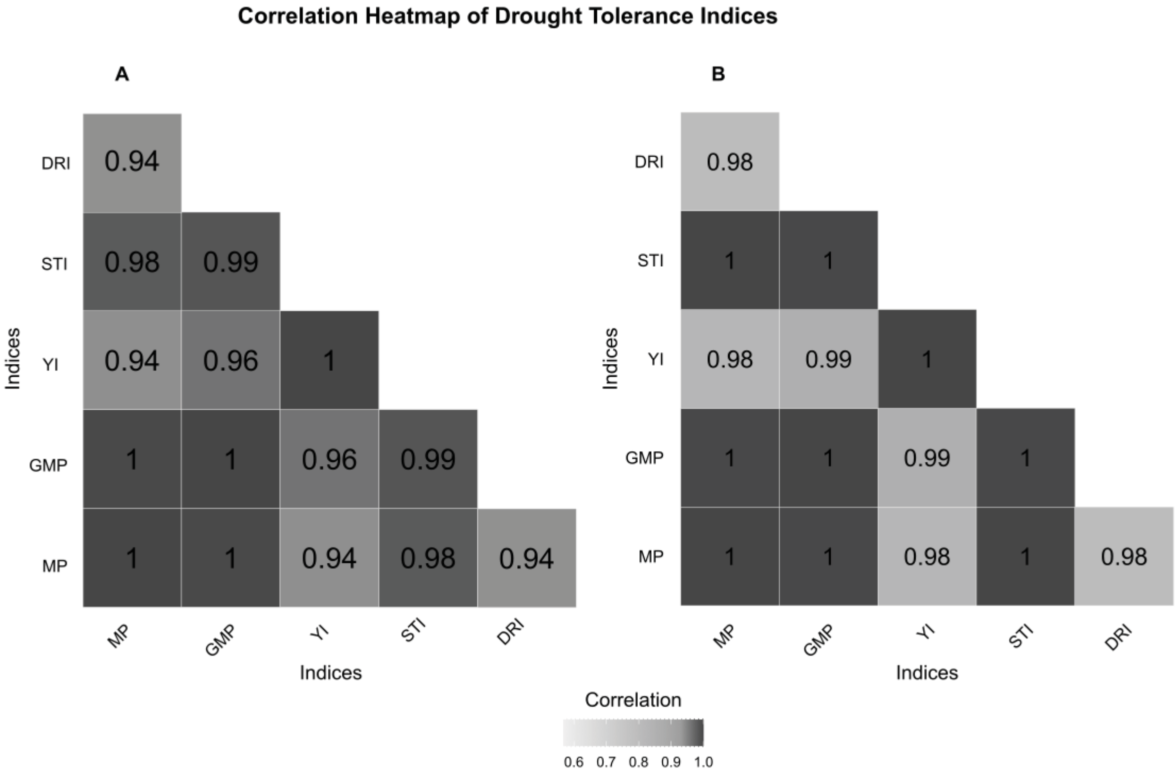

Fig. 19 Correlation Matrix of Drought Tolerance Indices. **A.** Intermittent drought **B.** Complete drought. Strong positive correlations are indicated by higher r values, while moderate and weak correlations are represented by lower r values.

3.4.3 Cluster Analysis

The hierarchical clustering was done using all the measured parameters. Based on the hierarchical clustering analysis, the rice varieties "Ratomarso" and "Temase" show a close proximity, indicating similar characteristics and traits. On the other hand, the varieties "Chamase" and "Jhumke" are also closely linked, suggesting similarities in their genetic and phenotypic profiles. The varieties "Anjana" and "Lalchand" exhibit a strong association, indicating shared genetic backgrounds or similar environmental adaptations. Moreover, the varieties "Jhini" and "Shanti" are closely linked, with "Batebudo" showing a linkage to them and then further connected to "Chiudi". This clustering pattern implies that these varieties may share common genetic traits and could potentially have similar responses to environmental factors. Overall, the hierarchical clustering analysis identifies three main clusters among the rice varieties. Notably, the varieties from Baitadi are distinct from those in Kanchanpur and Dadeldhura, indicating significant genetic differentiation or adaptation to local environmental conditions in these regions (Fig. 20).

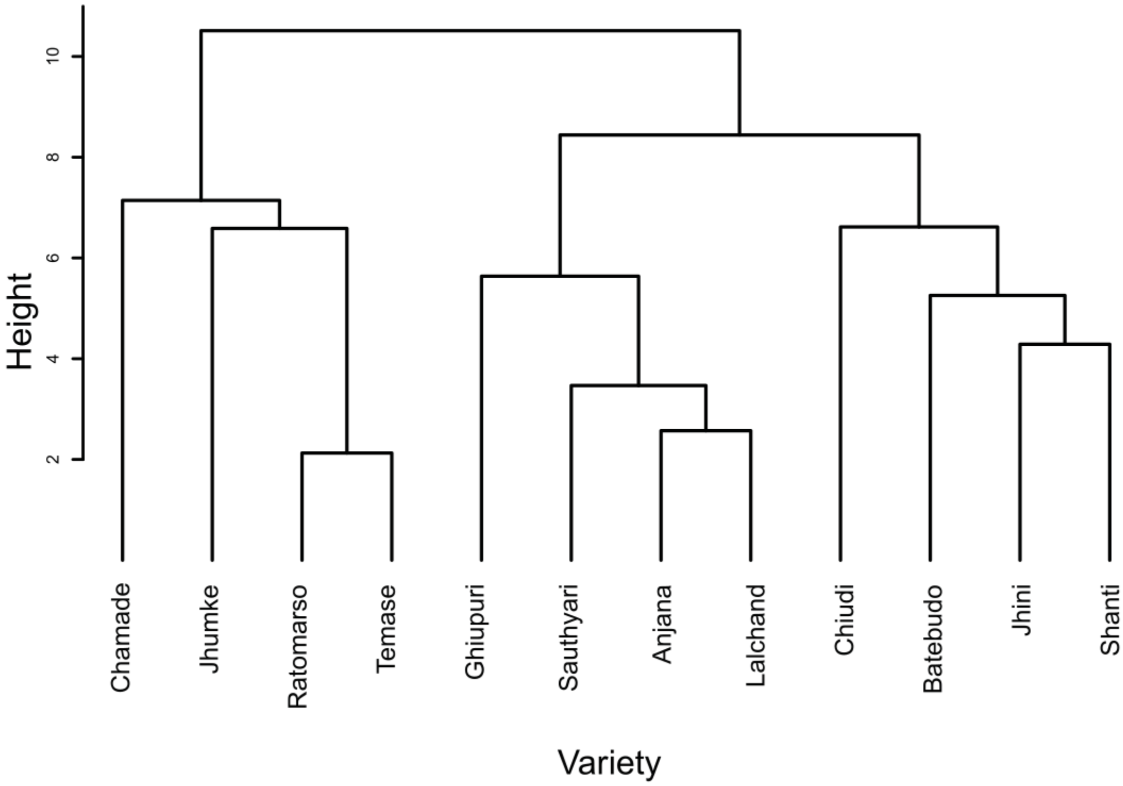

Fig. 20 Clustering of varieties based on the morph-physiological characters

3.4.4 AMMI2 biplot

The most effective approach for discerning the suitability of different crop varieties in withstanding drought conditions involves the utilization of the Additive Main Effect and Multiplicative Interaction model (AMMI) (Sabouri et al., 2022) .The AMMI2 biplot analysis was conducted to investigate the genotype-by-environment interactions and drought tolerance ability of rice varieties. The analysis revealed that the environmental effect and replication within environments significantly contributed to the total variation, suggesting the importance of environmental factors in shaping rice performance

The first principal component (PC1) explained 69.1% of the total dataset inertia, signifying that this component captured the primary sources of variability. The second principal component (PC2) accounted for an additional 30.9% of the total inertia, providing further insights into genotype and environmental effects (Fig. 21).

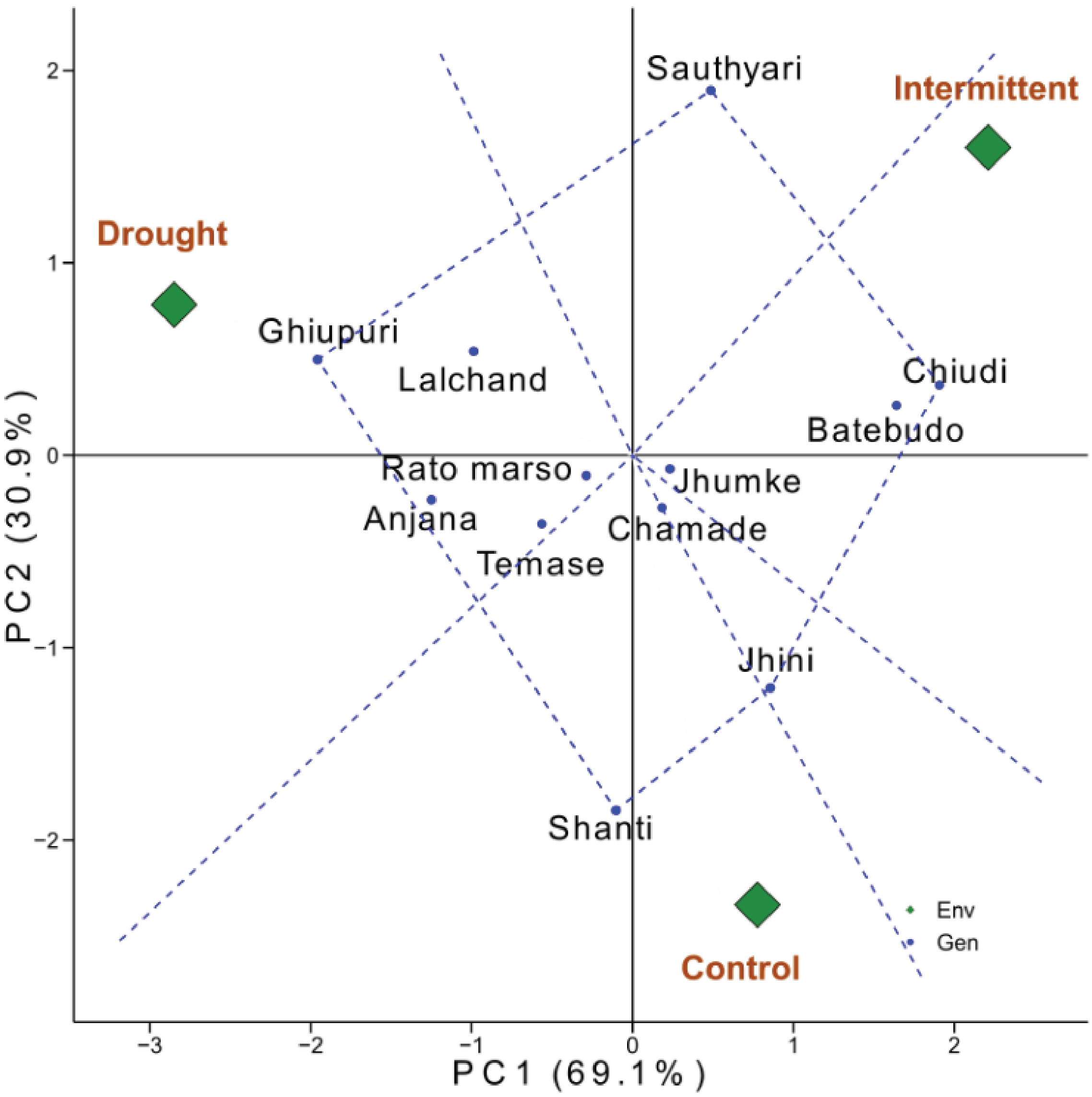

Fig. 21 Biplot analysis of varietal and treatment interaction based on AMMI2 model for first two interactions principal component scores.

In the AMMI2 biplot, each genotype and environment were represented as points in a two-dimensional space defined by PC1 and PC2. The genotype like Sauthyari, Chiudi, Batebudo are clustered in positive PC1 and PC2 scores. Conversely, varieties like Ratomarso, Anjana, Temase and Shanti are clustered in negative PC1 and PC2 space. Ghiupuri and Lalchand are in negative PC1 and positive PC2 space. Similarly, Jhumke, Chamade, Jhini are in Positive PC1 and negative PC2 space. Furthermore, the biplot illustrated the impact of different Treatments on genotype performance. The Control Treatment, represented by a negative PC2 score, seemed to have contrasting effects compared to the Drought and Intermittent treatment, represented by positive PC2 scores. In conclusion, the AMMI2 biplot analysis provided valuable insights into the genotype-by-treatment interactions and identified stable genotypes with consistent performance across environments. It appears that the genotypes Anjana, Ratomarso, Lalchand, Chamade, Jhumke and batebudo could be considered stable genotypes as they are clustered together near origion and show similar performance across the three treatments. These findings are crucial for the selection and breeding of rice varieties with improved drought tolerance and overall performance. By understanding how rice genotypes respond to different environments, we can make informed decisions to develop climate-resilient rice varieties, contributing to global food security amidst changing environmental conditions (Fig. 21).

4. DISCUSSION

4.1 Morphological characters

4.1.1 Number of tiller

The study investigated the impact of drought stress on tiller development in various rice landraces from different agroclimatic zone of farwest-Nepal. The results revealed distinct variations in tiller numbers across different rice varieties under control and drought stress conditions. In general the variety from Kanchanpur has higher tiller counts, followed by the Dadeldhura and Biatadi (Fig. 5) suggesting the effect of the environmental and agroclimatic factors on the tiller counts.

All the variety from Baitadi, Dadeldhura and Kanchanpur showed the decrease in the tiller count per hills, implying their vulnerability to reduced tiller development (Fig. 5) and suggesting a negative effect of the drought in the tiller count. But Jhumke variety is exception, it showed no significant differences in tiller count among treatments, indicating its relative tolerance to drought-induced tiller reduction (Fig. 5). Similarly, Chiudi variety demonstrated a unique response, with significantly higher tiller counts in the intermittent drought treatment compared to the control. This unexpected increase in tiller numbers might be attributed to genetic adaptability in Chiudi, allowing it to prioritize tiller production for survival during water scarcity. (Fig. 5)

These findings align with previous studies that have shown variations in tiller development under drought stress in different rice varieties. Chowhan et al. (2017) reported varied tiller numbers among modern rice varieties, similar to our finding. Mukamuhiwa et al. (2019) also observed a decrease in tiller numbers due to drought conditions, consistent with our study's results. The observed variations in tiller development under drought stress could be attributed to genetic differences among rice varieties, physiological responses to stress, and environmental interactions. It is crucial to consider these unique characteristics when analyzing tiller development in rice (Faruk et al., 2009).

4.1.2 Hill height

The results indicate that both location, variety and treatments play significant roles in determining the hill height of rice plants. These findings align with previous studies on drought-tolerant rice genotypes conducted by Shrestha et al. (2016) who observed significant difference in plant height in response to drought.

The study of Barba et al. (2014) found significant differences in the length of different rice landraces when evaluating drought-tolerant rice landraces. The influence of drought stress on plant height has been extensively studied in various rice genotypes. Haque et al. (2016) investigated the effect of drought stress on phenology, morphology, and yield of Aus rice, reporting reduced plant height under drought stress. This is consistent with the findings in the present study, where most of the varieties displayed reduced hill height under drought treatments. The reduction in plant height under drought stress is attributed to the restriction of cell elongation, resulting in a reduction in internode length and ultimately leading to shorter plant height (Bhandari et al. 2022).

In present study, the height of the rice landraces from Kanchanpur and Dadeldhura are higher than that of the landraces (Fig. 6), this may be due to effect of agro climatic conditions that they are adapting into. Furthermore, the study findings are consistent with those of Shrestha et al. (2016), who found significant differences in the length of different rice landraces when evaluating drought-tolerant rice landraces and drought-tolerant rice genotypes in the mid-hills of Nepal, respectively. The significant effects of treatment on shoot length underscore the importance of water availability in rice growth. Under drought conditions, the restriction of cell elongation likely contributed to the reduction in internode length, resulting in shorter shoot lengths in most varieties.

4.1.3 Root length

The root length of rice varieties showed significant variation under different treatments and locations. Our study shows the varying the response of the rice variety in water stress, the findings emphasize the importance of length in rice growth under drought conditions. Chiudi shows the increase in the root length, Jhumke, Temase, Jhini, Lalchand shows a stable root length along with the treatment. And In Chamade, Ratomarso, Shanti, Anjana, Ghiupuri and Sauthyari there is decrease in root length in response to water stress condition (Fig.7). These varying response suggests that the intricate role of rice genotype and its response in drought.

Generally, longer root in drought is expected. And similar results in rice are also found by several research like Kim et al. (2020), Henery et al. (2012) and Wang et al. (2019). But some research also shows that, some variety of rice which are drought tolerant having higher root length in both well water and drought stress condition and (Fonta et al., 2022). Even some research shows the decrease in root due to drought (Tahere et al., 2000). This highlights that the root length is controlled by different factors and the environmental factors do play significant role but the genotype also should be considered.

Part of our research are in line with the research by Kim et al. (2020), who emphasized the importance of greater root length in deeper soil layers and thicker coarse roots among upland rice varieties for improved water uptake under drought stress. Similarly, our study showed that certain rice varieties such as Chiudi in drought treatments exhibited longer root lengths, indicating their potential for enhanced water uptake during drought conditions. Additionally, the study by Wang et al. (2019) on the root distribution and drought tolerance of hybrid rice in the Sichuan Basin area of China revealed that drought-tolerant rice varieties exhibited increased root length and numbers, particularly in specific soil layers. This enhanced root development contributed to their superior drought tolerance. The study conducted by Henry et al. (2012) investigated root attributes in 'Dublar' and 'IR64' rice varieties under control and drought conditions, which aligns with our own observations. They found that the drought-tolerant variety, Dublar, exhibited significantly greater root length compared to IR64 in both control and drought treatments. Our study's similar findings support the notion that specific rice varieties indeed respond differently in terms of root length under varying treatments, potentially influencing their drought tolerance. This variability in root length among rice varieties further underscores the influence of genetic factors and environmental conditions, including soil types, on root development.

The research conducted by Fonta et al. (2022) on Azucena and IR64 demonstrated deeper rooting in both well-watered and drought conditions. In our research also some varieties like Jhumke, Temase, Jhini, Lalchand, there is no effect of the water treatment in root system within themselves rather the variation among them is found, this can be attributed to their genotype which also indicates that these varieties are tolerant to water stress in some ectent as there is no negative impact of drought on root. In contrast, research By Tahere et al. (2000) Demonstrated that root length decrease in rice under stress. In our research also Chamade, Ratomarso, Shanti, Anjana, Ghiupuri and Sauthyari shows the decrease in shoot length due to water stress (Fig.7).

4.1.4 Root weight and moisture content

The results of the root weight analysis demonstrated that there is more or less stable root fresheweight, dry weight and moisture percentage in all the levels of water treatments within the variety. Some exception was observed in varieties like Ratomarso and Jhini, whose resehweighe was significantly reducecd by water stress treatment (Fig. 8). Similarly in terms of dry weight, the exceptions are Jhumke and Batebudo, whereas in terms of moisture percentage is Chamade variety (Fig. 8).

In the study,Wang et al. (2019) reported a positive correlation between root weight and drought tolerance, indicating that drought-tolerant varieties tend to have heavier roots. Our research partially aligns with their findings. Specifically, among the Baitadi varieties, the Jhumke variety exhibited the highest Stress Tolerance Index (STI) as shown in Table 11 and had a higher root dry weight. However, the weight of Jhumke's roots significantly decreased under drought treatment, as illustrated in Fig. 8. Similarly, the Batebudo variety also demonstrated a higher root dry mass initially. Like Jhumke, it experienced a significant reduction in root weight when subjected to water stress. Conversely, other varieties in our study had lower initial root weights, but these did not decrease significantly under water stress conditions.

Our study's findings are consistent with Chareesi et al. (2020) in terms of the influence of rice variety on root dry biomass. Chareesi et al. (2020) reported that different rice varieties exhibited varying levels of root dry biomass. Similarly, in our study, we also observed variations in root biomass among different rice varieties. However, our results contradict some finding in Chareesi et al. (2020), where they concluded that drought had no effect on root dry biomass. In contrast, in our study, we found that the root biomass of certain varieties, such as Jhumke and Batebudo, significantly decreased under drought treatments, indicating that drought had an impact on their root biomass. On the other hand, some other varieties showed no significant difference in root biomass (Fig. 8), under different treatments, aligning with the observations in Chareesi et al. (2020). Similarly Nahar et al. (2018), also stated that drought significantly reduced root dry weight compared to root fresh weight but our research findings doesn't align with them, this suggests that role of genotype in their biomass accumulation and their response in drought rather their just the role of treatment.

4.1.5 Shoot weight and moisture content

In the context of shoot weight, our analysis reveals a generally consistent pattern in shoot fresh weight, shoot dry weight, and shoot moisture percentage across various varieties (Fig. 9), although some exceptions are evident. Specifically, with regard to shoot fresh weight, we observed a reduction in Ratomarso and Chiudi varieties in response to drought treatment, while interestingly, the Ghiupuri variety exhibited an increment in shoot fresh weight under the same conditions.

Conversely, concerning dry weight, the Chiudi and Shanti varieties exhibited a significant reduction in response to drought treatment, whereas the Ghiupuri variety displayed an increment in dry weight. In terms of moisture percentage, we detected a statistically significant decline in moisture percentage in the Chamade and Ratomarso varieties, with increased dryness. Conversely, other varieties maintained a consistent moisture percentage across all levels of water treatment.

Our result is Consistent with Nahar et al. (2018), where Drought stress revealed Helash Bora's (SN06) high shoot fresh weight (84.81%) and Bora's (SN03) low shoot fresh weight (36.36%), emphasizing divergent varietal responses to drought. Our study also shows divergent varietal response to drought. However, our study did not find significant differences in shoot dry weight among the varieties under different treatments. This is in contrast to Uzzaman et al. (2015), who reported significant variation in plant dry matter weight among rice varieties. The discrepancy could be attributed to the specific experimental conditions, growth stages, or environmental factors, which may have affected the results differently in both studies. Uzzaman et al. (2015) reported significant variation in plant dry matter weight among rice varieties at 30, 60, and 90 days after transplanting (DAT). However, no significant variation was observed at harvest. This specific findings of Uzzaman et al. (2015) aligns with our findings.

4.2 Traits related to yield

4.2.1 Panicle length

Panicle characters is one of the important characters which can give a meaningful insight on how the rice responds to drought and its drought tolerance ability Kandel et al. (2022). Our study investigates the response of the different treatments, control, intermittent drought and drought in rice. The panicle length shows varying response according to the variety. In response to drought treatment, there was a consistent reduction in panicle length across all varieties, indicating a negative impact on panicle size due to drought stress (Fig. 10). This observation aligns with the findings of Yang et al. (2022) and Bassoung et al. (2015). Bassuong et al. 2015 has investigated the effect of the stress, including drought on the panicle length and overall rice production. They observed that the drought stress caused the panicle to become shorter, which in turn reduces the yield. However, Chamade, does not show a significant reduction in panicle length under intermittent and full drought conditions. This exception suggests that Chamade may possess a unique ability to maintain a stable panicle size despite adverse conditions.

Yang et al. 2022 reported that the mild drought can result in the increase in the panicle length, however the severe drought significantly reduces the panicle length. In this study, the Chiudi shows similar trends, where the intermittent drought has resulted in the significant increase in the panicle length but in other varieties that did not show these trends. This suggests that drought response varies according to the variety.

4.2.2 Grains

The present study aimed to investigate the impact of different water treatments (Control, Intermittent, and Drought) on grain yield and quality in various rice varieties. The results from the three-way ANOVA revealed significant effects of location, treatment, and variety on the total number of grains per panicle. Interestingly, most of the rice landraces showed no significant difference in grain production between control and intermittent and drought treatments, suggesting a level of resilience to water stress. However, Jhini and shanti varieties exhibited a considerable reduction in grain yield, indicating their sensitivity to prolonged water scarcity. These findings emphasize the importance of selecting drought-tolerant rice genotypes for specific environmental conditions to optimize grain yield and ensure food security in water-limited regions.

The study also explored the influence of water stress on the number of filled and non-filled grains per panicle. Although there is no significant difference in the number of grains per panicle due to drought in most of the varities, the number of filled grains is redued in thm, such kinds of response are shown by varieties like Ratomarso, Batebudo, Jhini and Shanti. Concurrently, an increase in non-filled grains was observed under water stress conditions in varieties like Temase, Jhini, Shanti, further contributing to reduced grain production. These results align with previous studies (Jin et al., 2013; Yang et al., 2019), which reported altered grain filling patterns and decreased grain yield under moisture stress. The impact of drought stress highlights its critical role in determining grain yield and quality in rice, making it a crucial stage to consider for effective water management strategies. But like the result of Jin et al., 2013 and Yang et al.2019, we did study the rice landraces that are thought to be drought tolerance by the farmers, so the stable grains per panicle under drought treatments was expected.

Similar to our research, the study of Haque et al., 2016 also demonstrated greater tolerance of certain varieties to drought stress, exhibiting less reduction in grain yield. This emphasizes the importance of selecting and promoting drought-tolerant genotypes suitable for specific agroclimatic conditions. The comparison also underscores the significance of regional variations in rice varieties' responses to water stress, reinforcing the need for region-specific varietal selection and water management practices to optimize rice production.

4.3 Biochemical parameters

4.3.1 Chlorophyll content

In the majority of the rice landraces, there were no discernible differences in chlorophyll and carotenoid content between treatments (Fig. 13, Fig. 14, Fig. 15). This implies that, for most of the varieties, exposure to drought conditions did not yield a statistically significant impact on chlorophyll and carotenoid levels. However, some distinct exceptions are encountered. Notably, the Ratomarso variety from Baitadi exhibited a reduction in chlorophyll a, chlorophyll b, and total chlorophyll levels in response to drought conditions. Similarly, the Ghiupuri variety from Kanchanpur demonstrated a reduction in both chlorophyll a, chlorophyll b, and carotenoid content when subjected to complete drought conditions (Fig. 15). Moreover, the Batebudo variety from Dadeldhura experienced a reduction specifically in carotenoid content in response to complete drought (Fig. 14).

Saha et al. (2020) explored the effects of drought stress on pigment content in five rice varieties and observed a substantial decrease in chlorophyll a, chlorophyll b, total chlorophyll, and carotenoid content. Nasrin et al. (2020) further supported these findings. Demonstrating a steady decline in chlorophyll-a, chlorophyll-b, total chlorophyll, and carotenoids during drought stress treatment. But our result contradicts with their findings, except some varieties mention above.

Interestingly, Nahakpam (2017) proposed that the chlorophyll stability index (CSI) is a crucial parameter for drought tolerance and grain yield. Genotypes with higher CSI showed increased activities of antioxidant enzymes, suggesting their better ability to maintain chlorophyll stability under drought conditions. This indicates that not only the absolute chlorophyll content but also its stability plays a vital role in conferring drought tolerance in rice plants. Moreover, Akram et al. (2013) investigated the photosynthetic rate of rice cultivars under drought stress and reported significant reductions in photosynthetic activity. Super-Basmati exhibited the highest reduction in photosynthetic rate, highlighting the variation in drought responses among different cultivars. Our findings align with Dahal and Tripathy (2012), where water stress led to a reduction in chlorophyll accumulation during the greening process in rice seedlings. This decrease was attributed to the reduced accumulation of chlorophyll biosynthetic intermediates, further supporting the sensitivity of chlorophyll synthesis to water stress. It is notable that the impact of drought stress on chlorophyll content varied among different rice varieties. BRRI Dhan-56 displayed relatively better resilience compared to other varieties (Saha et al., 2020). Additionally, the dwarf mutant line MT58 exhibited higher chlorophyll contents under water deficit conditions, suggesting its potential as a drought-resistant cultivar (Dahal and Tripathy, 2012). Our study contributes to the growing body of research on drought stress and chlorophyll content in rice plants. The observed reductions in chlorophyll content indicate the vulnerability of rice plants to water-deficit conditions. Understanding the variations in chlorophyll content and stability among different rice varieties is essential for developing strategies to enhance drought tolerance and agricultural productivity under water-limited conditions. In conclusion, our finding, along with the evidence from other research articles, emphasize the significance of chlorophyll content in rice plants under drought stress. The identification of genotypes with higher chlorophyll stability and content can aid in the selection of drought-tolerant cultivars, which may ultimately contribute to sustainable rice production in regions prone to water scarcity. However, further studies are required to elucidate the underlying molecular mechanisms governing chlorophyll synthesis and stability under drought stress, providing valuable insights for crop improvement and water management strategies.

4.3.2 Catalase activity

The result indicates the influence of location, variety, and treatment on the enzyme's response. The results from Baitadi demonstrated that Chamade variety showed the highest catalase activity in all three treatments, indicating its potential to efficiently scavenge hydrogen peroxide and combat oxidative stress induced by drought. Similarly, in Dadeldhura, the Batebudo variety exhibited higher catalase activity under drought stress, signifying its capacity to cope with oxidative damage caused by water deficit conditions. Interestingly, some varieties, such as Jhumke and Ratomarso, showed a significant increase in catalase activity between the drought and control treatments, suggesting their adaptive response to water scarcity, while others, like Chiudi and Shanti, did not exhibit significant differences, implying the involvement of alternative antioxidant mechanisms in their drought response.

Comparing our findings with previous research articles, we noted that catalase activity has been consistently reported to increase under drought stress in rice and other plant species. The study by Roy et al. (2009) further supported our results, as they found a higher catalase activity indicates the higher drought resistance in rice genotypes. Similarly, Saha et al. (2020) observed an increase in catalase activity in rice varieties under drought stress, reinforcing the notion that this enzyme plays a crucial role in combating oxidative stress during water deficit conditions. However, the impact of drought on catalase activity varied among different rice varieties, as evidenced by Fen et al. (2015). Some varieties exhibited increased catalase activity under stress, while others maintained higher activity levels under well-watered conditions. These discrepancies highlight the complexity of drought responses among different rice genotypes and emphasize the need for a comprehensive understanding of the underlying mechanisms.

The study by Fen et al. (2015) found that the catalase activity in rice varieties was not significantly affected by water supply treatments but varied among the different rice varieties. MR 220 and IRRI 2011-IRLON Plot no: 050 were the only two varieties that showed a significant difference in catalase activity under different irrigation treatments in their study. They also notice that, catalase activity decreased during water stress. MR 220 and MR 9 exhibited higher catalase activity during well-watered conditions, while MR 84 and MR 9 showed higher catalase activity under water stress. The average catalase activity in control plots was 2161.3 µmol/mg protein/min, whereas in drought plots, it was reduced to 207.9 µmol/mg protein/min. (Fen et al. 2015)

Similarly, in the study conducted by Saha et al. (2020), drought stress induced a significant increase in catalase activity in leaves of different rice varieties. Notably, BRRI Dhan-56 exhibited the highest increase of 37.67% in catalase activity after 15 days of stress treatment, while other varieties (BRRI Dhan-30, BRRI Dhan-32, BRRIDhan-34, and BRRI Dhan-38) also displayed substantial increases ranging from 7.65% to 22.59% during the same period. These results further emphasize the critical role of catalase in mitigating oxidative damage during water deficit conditions and provide valuable insights for the development of drought-tolerant rice cultivars, contributing to food security in water-scarce regions.

4.4 Correlation between parameters

The analysis of correlations between different parameters in our study has provided valuable insights into the factors influencing rice yield and drought tolerance, aligning with previous research in this area. Our findings regarding the positive correlation between root length and the number of tillers are consistent with the results reported by Panda et al. (2021) and Gowda et al. (2011). They also found that well-developed root systems positively influenced tiller production in rice under drought stress.

The negative correlation between root moisture content and the number of tillers per hills observed in our study is in agreement with the findings of Usman et al. (2013) and Nahar et al. (2018). These studies also reported that decreased root moisture content was associated with increased tiller formation, indicating that water stress might trigger physiological responses leading to more tiller production.

The positive correlation between yield and the number of tillers found in our study is in line with the findings of Moonmoon and Islam (2017) and Divya (2020). They also reported that higher tiller numbers were associated with increased yield in rice, highlighting the importance of tiller production in determining overall grain yield.

Regarding root length and hill height, the lack of a significant correlation in our study aligns with the work of Panda et al. (2021), who also reported no significant relationship between these two parameters. However, the negative correlation between root moisture content and hill height in our study is supported by the findings of Gowda et al. (2011) and Panda et al. (2021), who observed that increased hill height was associated with reduced root moisture content under water stress conditions.

The positive correlation between shoot moisture percentage and root moisture percentage found in our study is consistent with the results reported by Nahar et al. (2018), suggesting that shoot and root moisture content may be linked.

The lack of a significant correlation between yield and shoot moisture percentage in our study is in contrast to the findings of Sujit and Sarkar (2003) and Kumar et al. (2023), who reported a positive correlation between these two parameters. This disparity may be attributed to variations in experimental conditions and genetic diversity among rice varieties.

In conclusion, our study has provided valuable insights into the correlations between different parameters influencing rice yield and drought tolerance. These findings align with existing literature, supporting the importance of root length, tiller production, and shoot and root moisture content in determining rice yield under drought conditions. Comparisons with other studies have strengthened the robustness of our results and highlighted the need for further research to fully elucidate the complexities of drought tolerance in rice. Our study contributes to the growing body of knowledge in this field and paves the way for developing drought-tolerant rice varieties and sustainable agricultural practices.

Our observation of a positive correlation between root length and yield, particularly in drought treatments, contrasts with the findings of Bhandari et al. (2023), who reported no significant correlation between these two parameters. This discrepancy may be attributed to variations in experimental conditions, including soil type, water availability, and rice varieties used in the studies.

Furthermore, our analysis did not reveal any significant correlation between root moisture content and shoot length, which contrasts with the findings of Nahar et al. (2018), who reported a significant positive correlation between these two parameters in rice plants under different stress conditions. The variation in these results may be attributed to different genetic backgrounds and environmental factors influencing the relationship between root moisture content and shoot length. Regarding the correlation between root length and hill height, our study found no significant relationship, which is contrary to the results reported by Kumar et al. (2023). They observed a positive correlation between these parameters in their study, suggesting that increased root length was associated with greater hill height in rice plants under water stress conditions. The differences in experimental designs and rice varieties used in the two studies may contribute to these contrasting results.

In conclusion, while our study has provided valuable and consistent insights into the correlations between certain parameters and drought tolerance in rice, there are also some contrasting results compared to other research findings. These discrepancies highlight the complexity of drought tolerance mechanisms in rice and the need for further research to fully understand and elucidate the underlying factors influencing these correlations. The variations in experimental conditions, genetic diversity among rice varieties, and environmental factors play crucial roles in shaping the outcomes of these studies. Our study contributes to the broader understanding of drought tolerance in rice and encourages future investigations to build a comprehensive and robust understanding of this important trait for sustainable agriculture.

4.5 Drought tolerance indices

Our findings revealed significant variation in drought tolerance among the tested varieties. Jhumke exhibited the highest drought tolerance in Baitadi, followed by Chamade, while in Dadeldhura, Batebudo displayed remarkable tolerance, with Chiudi exhibiting moderate drought tolerance. Among the varieties in Kanchanpur, Anjana displayed moderate drought tolerance, while Sauthiyari showed the highest drought tolerance. These results provide valuable insights into selecting suitable rice varieties for cultivation in drought-prone areas of western Nepal and emphasize the importance of continued research to enhance crop resilience to water stress. The study conducted by Farshadfar et al. (2012) evaluated the drought tolerance in various landrace bread wheat genotypes, focusing on thirteen different drought tolerance indices. These indices emerged as robust discriminators of drought-tolerant genotypes, suggesting their suitability for identifying genotypes with superior drought tolerance.

Our research results align with the findings of Talebi et al. (2008), as we also observed significant and positive correlations between yield index (YI) and various indices, such as mean productivity (MP), geometric mean productivity (GP), and stress tolerance index (STI). These indices demonstrated greater effectiveness in identifying high-yielding cultivars under diverse moisture conditions. Additionally, Talebi et al. (2008) revealed that indirect selection based on moisture-stress environment led to greater improvements in yield under such conditions compared to selection based on non-moisture stress environments.

In conclusion, both our study and the works of Farshad et al. (2012) and Talebi et al. (2008) underscore the significance of utilizing multiple drought tolerance indices for effective genotype screening and selection. The identified drought-tolerant genotypes hold substantial promise for contributing to enhanced resilience and productivity in water-limited environments. As the global challenges of drought and water scarcity persist, the insights from our research and related studies can guide rice breeders in making informed decisions, ultimately contributing to the sustainable improvement of bread wheat production in regions prone to drought stress.

4.6 Multivariate analysis

The best way to understand which varieties can handle drought is through genotype-environmental interaction (Sabouri et al., 2022), among them the AMMI2 plot (Additive main effect and multiplicative interaction) is widely used method (Lingaiah et al., 2020) In our research, we observed that the types of rice like Ratomarso, Anjana, Temase, Chamase, Jhumke, and Batebudo remain quite stable when faced with normal, intermittent drought, and severe drought conditions. However, Ghiupuri seems to do well during severe drought, sauthyari performs well when the dryness comes and goes, and Shant thrives in regular conditions. These conclusions are based on all the factors we measured. This is consistent with the findings of Muthuramu et al. (2011), who also observed significant effects of variety and location in their PCA analysis for drought tolerance in rice. Our findings align with those of other studies that have also utilized PCA to assess drought tolerance in rice. Beena et al. (2021) reported similar results, where the first two dimensions of PCA explained a substantial portion of the total variance, indicating their relevance in evaluating drought responses. Additionally, they observed distinct separations of rice landraces based on their drought tolerance abilities, which reinforces the robustness of PCA as a tool for identifying drought-tolerant genotypes.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, our study reveals important differences in how various types of rice landraces respond to different water conditions. In this study, when rice plantations faced with water stress, most rice landraces showed a decrease in the number of tillers, root length and hill height. Interestingly, many landraces showed the stable root and shoot weights. The water stress caused the reduction in the panicle length while the number of grains per panicle remained stable, but the actual yield was reduced due to the stress. On the biochemical level, these plants managed to maintain their chlorophyll content, indicating their resilience in sustaining photosynthesis. Interestingly, they responded to water stress by increasing catalase activity, a sign of adaptation to cope with the stress. The research also highlights the intricate interplay of genetic factors, environmental conditions, and treatment effects on various aspects of rice growth and development, particularly under drought stress. Moreover, the study emphasizes the complex interplay of biochemical markers like catalase activity in rice's drought response. Identifying key mechanisms underlying these responses holds promise for enhancing drought tolerance and sustainable agriculture. Our initial hypothesis was that the morphoagronomic characteristics and biochemical properties of rice landraces would vary across different water stress conditions and agroclimatic zones within the region. Our findings partially support this hypothesis. Morphoagronomic characteristics did indeed vary across agroclimatic zones and treatments, but the primary factor influencing these variations was the rice variety itself. Therefore, we cannot make broad generalizations.

Furthermore, present study also demonstrated substantial variation in drought tolerance among the tested rice varieties. Jhumke exhibited the highest level of drought tolerance in Baitadi, followed by Chamade. In the Dadeldhura, Batebudo displayed remarkable tolerance to drought stress, while Chiudi exhibited moderate drought tolerance. Similarly, in Kanchanpur, Anjana displayed a moderate level of drought tolerance, whereas Sauthiyari exhibited the highest level of drought tolerance among all tested varieties. These findings provide critical insights for selecting suitable rice varieties for cultivation in drought-prone regions of western Nepal. Studies of this nature are instrumental in determing climate-resilient rice varieties that can thrive in challenging environmental conditions, thereby contributing to sustainable agriculture in drought-affected areas.

5.2 Recommendation

Based on the investigation of the impact of drought stress on different growth parameters, physiological responses, and biochemical response in 12 rice landraces from far-west Nepal, the findings of this research offer significant insights and implications for practical applications and future studies in agriculture. The results demonstrate the importance of considering location, variety, and treatment effects when evaluating rice plant responses to drought stress. Therefore, the following recommendations are suggested:

1. Among the studied varieties, Jhini from Baitadi, Batebudo from Dadeldhura, and Sauthyari from Kanchanpur district show strong resilience to drought conditions. Therefore, these varieties are recommended for cultivation in regions as drought resilient varieties.
2. Regional Specificity in Crop Management:

   The significant variations observed in rice responses to drought stress across different locations emphasize the importance of regional specificity in crop management strategies. It is recommended to consider location-specific factors, such as climate and water availability, when selecting and implementing appropriate rice varieties and water management practices. This will optimize crop performance and promote sustainable agriculture in each specific agro-climatic region.

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ANNEXES

Annex-1. Moisture content (%) in experimental plot.

Location	Variety	Treatment		
		Control	Intermittent	Drought
Baitadi	Chamade	62.56 ± 15.4	48.24 ± 7	27 ±8.8
	Jhumke	58.72 ± 17.7	49.36 ± 8.4	29.16 ± 9.4
	Ratomarso	80.04 ± 13.7	46.88 ± 13.5	16.68 ± 7.2
	Temase	84.64 ± 12.1	42.32 ± 13.6	21.64± 11.7
Dadeldjhura	Batebudo	70.32 ± 11.4	48.64 ± 6.5	29.88 ± 9.8
	Chiudi	64.72 ± 15	47.36 ± 5.7	23 ± 1.4
	Jhini	65.56 ± 10.7	44.28 ± 4.8	30.2 ± 2.7
	Shanti	70.12 ± 16.2	44.04 ± 7.3	26.24 ± 4.5
Kanchanpur	Anjana	62 ± 15.5	48.4 ± 11.7	30.64 ± 9.5
	Ghiupuri	65.6± 15.6	49.04 ± 18.6	33.92 ± 14.1
	Lalchand	69.44 ± 20.4	49 ± 17.6	28.2 ± 6.6
	Sauthyari	77.8 ± 15.3	50 ± 16.3	30.2 ± 6.5

Annex-2. Morphological characters

[Rep=Replication, M%=Moisture percentage, No.T=Number of tillers per hills, HH=Hill height, SL=shoot length, RL=Root length, RFW=Root fresh weight,Rn=Root dry weight]

Location	Variety	Treatment	Rep	M%	No.T	HH	SL	RL	RFW	RDW	SFW	SDW
Kanchanpur	Anjana	Control	1	62	10.6	101.0	74.9	18.7	65.1	25.6	529.3	135.6
Kanchanpur	Anjana	Control	2	75	11.3	84.8	55.3	13.8	31.0	16.0	349.8	120.2
Kanchanpur	Anjana	Control	3	44	9.8	102.0	75.5	18.9	77.3	30.7	429.5	123.5
Kanchanpur	Anjana	Control	4	44	10.5	101.0	75.0	18.8	96.5	30.0	439.0	134.7
Kanchanpur	Anjana	Control	5	65	11.3	88.4	61.3	15.3	137.6	41.3	446.4	147.2
Kanchanpur	Anjana	Intermittent	1	64	10.2	76.3	61.9	12.4	79.3	19.4	393.7	134.5
Kanchanpur	Anjana	Intermittent	2	58	7.7	74.9	66.8	12.0	157.8	59.9	476.8	150.6
Kanchanpur	Anjana	Intermittent	3	62	10.9	88.3	69.4	15.3	86.7	23.8	352.3	102.3
Kanchanpur	Anjana	Intermittent	4	66	8.7	77.1	78.0	13.0	73.9	18.2	348.6	122.3
Kanchanpur	Anjana	Intermittent	5	65	11.3	82.3	66.1	13.6	133.4	35.3	361.5	129.3
Kanchanpur	Anjana	Drought	1	36	10.4	89.1	49.6	15.5	86.4	24.0	397.7	120.3
Kanchanpur	Anjana	Drought	2	49.2	8.3	94.3	47.9	16.7	100.9	31.5	422.4	157.8
Kanchanpur	Anjana	Drought	3	33	9.8	96.5	61.3	17.3	52.0	17.8	364.4	123.4
Kanchanpur	Anjana	Drought	4	30	10.9	105.0	52.0	19.5	112.5	32.7	383.4	135.4
Kanchanpur	Anjana	Drought	5	34	10.0	92.3	54.5	16.5	111.3	34.9	461.0	121.6
Dadeldhura	Batebudo	Control	1	17	8.5	124.0	72.0	12.2	134.2	58.8	1225.3	309.8
Dadeldhura	Batebudo	Control	2	16	7.4	110.0	74.3	7.7	69.1	30.7	724.9	204.6
Dadeldhura	Batebudo	Control	3	19	6.9	109.0	75.1	9.4	82.2	30.2	625.0	211.9
Dadeldhura	Batebudo	Control	4	92.6	9.3	103.0	74.3	8.9	127.1	50.4	902.6	354.7
Dadeldhura	Batebudo	Control	5	20.4	7.8	126.0	76.4	10.8	87.9	31.4	929.7	245.6
Dadeldhura	Batebudo	Intermittent	1	16	6.8	117.0	72.8	12.0	117.2	35.6	1031.1	279.5
Dadeldhura	Batebudo	Intermittent	2	15.4	6.7	115.0	72.5	10.1	360.2	150.7	790.3	275.6
Dadeldhura	Batebudo	Intermittent	3	14.8	5.7	107.0	72.0	7.5	138.7	34.5	885.2	276.8
Dadeldhura	Batebudo	Intermittent	4	18.6	7.1	111.0	74.0	10.3	107.1	36.7	938.3	257.6
Dadeldhura	Batebudo	Intermittent	5	22	4.4	111.0	72.0	10.2	155.9	65.4	955.3	247.6
Dadeldhura	Batebudo	Drought	1	12.2	5.6	122.0	64.3	10.8	205.7	96.5	839.5	245.6
Dadeldhura	Batebudo	Drought	2	10	5.4	113.0	65.9	12.6	116.1	54.5	617.1	214.8
Dadeldhura	Batebudo	Drought	3	10.8	6.7	118.0	64.0	9.0	106.2	43.2	923.3	233.3
Dadeldhura	Batebudo	Drought	4	12.4	6.6	125.0	65.4	10.9	110.4	39.8	552.5	121.9
Dadeldhura	Batebudo	Drought	5	13	6.0	111.0	63.4	8.9	116.2	46.5	587.0	204.5
Baitadi	Chamade	Control	1	42.4	3.3	91.3	98.3	9.9	121.7	26.3	310.3	62.0
Baitadi	Chamade	Control	2	53.4	3.6	92.3	94.0	9.3	108.3	26.4	298.9	59.2
Baitadi	Chamade	Control	3	62.4	3.1	209.0	99.3	9.3	123.1	27.8	335.5	70.3
Baitadi	Chamade	Control	4	56.2	3.4	88.8	98.2	9.8	150.5	31.0	301.4	63.5
Baitadi	Chamade	Control	5	70.6	3.1	81.9	90.3	10.5	104.9	23.3	321.8	65.6
Baitadi	Chamade	Intermittent	1	69.2	3.4	95.5	103.7	9.5	153.9	32.5	355.2	71.0
Baitadi	Chamade	Intermittent	2	45	3.1	94.3	104.3	7.6	93.9	22.1	283.8	69.7
Baitadi	Chamade	Intermittent	3	52.8	2.7	81.9	104.5	8.3	144.5	33.1	363.0	75.3
Baitadi	Chamade	Intermittent	4	47	2.9	89.0	97.3	7.5	164.3	40.0	284.3	71.8

Baitadi	Chamade	Intermittent	5	54.6	2.7	73.5	104.5	8.1	129.6	25.6	287.5	73.5
Baitadi	Chamade	Drought	1	21.4	3.4	83.3	82.3	11.3	115.9	32.5	212.5	54.6
Baitadi	Chamade	Drought	2	23.4	3.2	90.1	92.3	7.4	113.1	33.9	360.0	78.8
Baitadi	Chamade	Drought	3	27.4	2.9	85.0	80.6	8.0	90.0	22.8	278.5	60.8
Baitadi	Chamade	Drought	4	36.8	2.9	83.9	82.8	8.3	65.0	19.2	185.5	49.2
Baitadi	Chamade	Drought	5	26	3.4	83.8	83.0	8.2	79.9	20.8	290.5	68.5
Dadeldhura	Chiudi	Control	1	17	5.6	119.0	101.5	7.3	98.7	35.6	710.2	208.6
Dadeldhura	Chiudi	Control	2	16	5.7	113.0	97.8	8.5	122.1	45.6	645.2	205.4
Dadeldhura	Chiudi	Control	3	19	6.5	106.0	88.2	8.3	177.4	76.5	409.3	155.5
Dadeldhura	Chiudi	Control	4	92.6	4.7	116.0	96.7	9.4	150.0	67.8	549.7	192.4
Dadeldhura	Chiudi	Control	5	20.4	5.7	93.8	77.6	9.1	152.0	64.5	640.3	184.5
Dadeldhura	Chiudi	Intermittent	1	16	4.3	112.0	96.3	12.2	65.0	22.5	931.9	250.4
Dadeldhura	Chiudi	Intermittent	2	15.4	4.8	119.0	96.2	9.2	157.0	70.8	684.1	276.0
Dadeldhura	Chiudi	Intermittent	3	14.8	3.1	113.0	114.6	7.3	122.0	44.6	719.8	245.5
Dadeldhura	Chiudi	Intermittent	4	18.6	2.7	118.0	112.2	8.7	123.0	40.3	497.1	184.5
Dadeldhura	Chiudi	Intermittent	5	22	5.1	112.0	100.2	10.3	144.0	45.6	762.9	196.0
Dadeldhura	Chiudi	Drought	1	12.2	6.8	113.0	95.2	9.5	91.0	34.5	424.9	157.2
Dadeldhura	Chiudi	Drought	2	10	5.8	117.0	96.8	9.4	108.0	39.8	342.2	121.5
Dadeldhura	Chiudi	Drought	3	10.8	4.9	130.0	104.1	8.3	205.0	71.3	288.4	97.8
Dadeldhura	Chiudi	Drought	4	12.4	5.9	133.0	91.1	8.8	154.0	59.8	489.4	186.4
Dadeldhura	Chiudi	Drought	5	13	5.2	120.0	94.5	9.5	118.0	48.7	324.2	135.6
Kanchanpur	Ghiupuri	Control	1	75	8.9	86.5	57.5	14.4	38.4	13.6	370.3	115.3
Kanchanpur	Ghiupuri	Control	2	73	10.7	85.9	57.3	14.3	57.1	11.9	295.2	98.3
Kanchanpur	Ghiupuri	Control	3	46	10.7	102.0	73.3	18.3	24.1	7.7	328.3	103.1
Kanchanpur	Ghiupuri	Control	4	53	11.2	90.7	63.8	15.9	54.7	15.6	299.5	110.9
Kanchanpur	Ghiupuri	Control	5	64	10.8	88.9	59.5	14.9	85.5	23.7	277.9	107.8
Kanchanpur	Ghiupuri	Intermittent	1	69	10.4	78.3	53.9	12.3	47.6	23.8	299.9	94.6
Kanchanpur	Ghiupuri	Intermittent	2	51	8.0	78.3	67.4	12.3	37.2	17.1	342.4	115.7
Kanchanpur	Ghiupuri	Intermittent	3	58	7.5	75.5	57.0	11.7	35.7	24.5	393.8	122.4
Kanchanpur	Ghiupuri	Intermittent	4	71	10.8	92.0	70.6	15.8	59.4	17.8	330.8	91.0
Kanchanpur	Ghiupuri	Intermittent	5	98	10.4	78.4	64.5	12.0	69.9	19.3	379.4	94.5
Kanchanpur	Ghiupuri	Drought	1	62	11.0	82.4	49.1	13.5	25.1	14.0	487.7	135.4
Kanchanpur	Ghiupuri	Drought	2	36	7.7	95.3	49.1	16.8	31.7	22.3	352.4	123.4
Kanchanpur	Ghiupuri	Drought	3	39.6	9.8	86.3	46.9	14.2	32.9	8.8	419.6	120.6
Kanchanpur	Ghiupuri	Drought	4	32	11.8	98.9	63.1	17.7	62.5	21.5	421.0	136.7
Kanchanpur	Ghiupuri	Drought	5	28	8.4	94.4	48.0	16.1	53.5	21.1	372.9	117.7
Dadeldhura	Jhini	Control	1	16.6	5.0	137.0	101.5	10.1	131.9	35.5	1122.2	259.8
Dadeldhura	Jhini	Control	2	42.8	3.1	130.0	97.8	8.3	132.6	38.0	626.7	157.2
Dadeldhura	Jhini	Control	3	42.6	7.8	151.0	88.2	11.2	136.4	52.0	654.6	195.2
Dadeldhura	Jhini	Control	4	18	3.8	127.0	96.7	8.6	138.8	47.2	808.7	254.5
Dadeldhura	Jhini	Control	5	19.6	4.4	114.0	77.6	8.5	139.5	48.5	612.9	167.8
Dadeldhura	Jhini	Intermittent	1	15	3.0	128.0	96.3	8.2	124.2	28.8	1021.7	226.6
Dadeldhura	Jhini	Intermittent	2	14.4	4.2	111.0	96.2	8.4	148.1	81.2	625.1	221.4

Dadeldhura	Jhini	Intermittent	3	13	2.6	129.0	114.6	10.8	129.9	49.0	822.9	191.9
Dadeldhura	Jhini	Intermittent	4	13	3.2	106.0	112.2	11.2	130.5	45.0	585.7	229.4
Dadeldhura	Jhini	Intermittent	5	16	4.2	110.0	100.2	9.2	127.0	48.5	569.2	172.0
Dadeldhura	Jhini	Drought	1	10	4.9	135.0	95.2	9.2	129.6	43.1	485.9	143.5
Dadeldhura	Jhini	Drought	2	12.2	3.3	148.0	96.8	7.0	119.9	41.9	383.3	134.7
Dadeldhura	Jhini	Drought	3	10	3.3	118.0	104.1	10.2	122.8	60.5	728.6	187.3
Dadeldhura	Jhini	Drought	4	12	2.7	126.0	91.1	8.7	117.7	52.2	790.3	244.5
Dadeldhura	Jhini	Drought	5	11.8	3.4	133.0	94.5	9.2	114.5	46.8	526.9	198.6
Baitadi	Jhumke	Control	1	77.8	3.3	56.8	47.8	11.3	239.6	64.4	231.9	50.7
Baitadi	Jhumke	Control	2	70.4	3.4	67.1	49.8	9.2	138.4	42.8	164.8	50.1
Baitadi	Jhumke	Control	3	46.6	3.3	66.0	54.5	10.6	213.6	54.2	249.0	52.3
Baitadi	Jhumke	Control	4	54	3.3	64.8	48.1	9.9	163.2	41.6	276.9	61.3
Baitadi	Jhumke	Control	5	36	3.4	63.3	54.4	8.5	161.3	44.5	186.9	48.1
Baitadi	Jhumke	Intermittent	1	58.6	3.6	65.1	46.7	11.4	132.6	40.0	206.3	57.1
Baitadi	Jhumke	Intermittent	2	58.8	3.4	65.0	55.1	9.1	122.1	37.7	248.1	55.8
Baitadi	Jhumke	Intermittent	3	64	2.8	59.2	51.3	10.2	355.0	84.0	199.8	50.0
Baitadi	Jhumke	Intermittent	4	54	3.1	59.7	52.4	9.6	193.0	64.0	247.2	65.0
Baitadi	Jhumke	Intermittent	5	58.4	2.7	59.1	52.0	10.1	188.9	47.2	199.9	55.7
Baitadi	Jhumke	Drought	1	24	3.3	63.8	51.5	9.7	130.0	38.6	175.4	41.7
Baitadi	Jhumke	Drought	2	24	3.4	63.0	44.2	10.1	65.6	30.4	187.2	50.1
Baitadi	Jhumke	Drought	3	42.2	3.0	65.2	52.4	10.9	100.1	34.5	198.5	57.1
Baitadi	Jhumke	Drought	4	29.2	3.0	63.9	51.0	9.3	78.5	24.5	191.7	65.8
Baitadi	Jhumke	Drought	5	26.4	3.1	68.0	51.4	11.3	141.9	42.4	249.3	57.0
Kanchanpur	Lalchand	Control	1	70.2	9.8	83.2	64.4	16.0	116.4	38.7	646.7	162.9
Kanchanpur	Lalchand	Control	2	73	11.3	95.5	71.5	17.9	145.7	40.9	631.7	154.3
Kanchanpur	Lalchand	Control	3	70	10.9	95.1	71.5	17.9	153.7	27.0	408.8	108.5
Kanchanpur	Lalchand	Control	4	44	11.9	103.0	78.6	19.7	134.0	35.2	447.8	139.7
Kanchanpur	Lalchand	Control	5	90	10.4	95.5	71.8	17.8	161.9	40.8	432.4	136.8
Kanchanpur	Lalchand	Intermittent	1	75	11.5	74.4	73.6	14.1	114.4	51.1	682.5	165.5
Kanchanpur	Lalchand	Intermittent	2	74	9.8	78.3	67.3	14.7	103.4	45.1	557.2	164.5
Kanchanpur	Lalchand	Intermittent	3	60	10.4	91.3	62.8	17.2	52.9	20.3	597.2	149.0
Kanchanpur	Lalchand	Intermittent	4	63	10.7	84.1	70.5	15.4	123.1	30.9	638.1	169.0
Kanchanpur	Lalchand	Intermittent	5	87	9.6	77.4	68.5	15.0	102.7	29.5	560.1	152.5
Kanchanpur	Lalchand	Drought	1	33	9.5	97.2	56.0	18.5	98.5	33.3	619.3	160.6
Kanchanpur	Lalchand	Drought	2	43	7.4	88.8	58.4	16.9	121.8	58.3	580.4	167.8
Kanchanpur	Lalchand	Drought	3	28	8.2	85.3	68.5	15.8	81.6	24.2	599.5	205.7
Kanchanpur	Lalchand	Drought	4	31	10.3	92.6	61.3	17.7	109.2	34.6	550.3	198.7
Kanchanpur	Lalchand	Drought	5	32	11.2	89.8	59.8	17.2	200.4	72.5	436.8	134.7
Baitadi	Rato marso	Control	1	86	3.2	67.0	54.5	11.0	80.9	17.5	143.1	33.0
Baitadi	Rato marso	Control	2	87.4	3.1	69.2	53.2	11.2	79.7	15.6	156.0	35.0
Baitadi	Rato marso	Control	3	91	3.0	71.6	53.6	12.4	107.8	23.6	185.8	45.5
Baitadi	Rato marso	Control	4	63	3.0	67.3	51.8	11.9	30.6	9.8	163.2	41.8
Baitadi	Rato marso	Control	5	72.8	2.9	69.6	52.5	14.6	131.5	26.0	191.0	40.2

Baitadi	Rato marso	Intermittent	1	60.8	2.9	79.3	45.5	9.4	89.9	24.1	179.7	43.0
Baitadi	Rato marso	Intermittent	2	62	2.6	68.3	52.6	10.8	49.3	12.0	155.3	42.4
Baitadi	Rato marso	Intermittent	3	37.6	2.8	68.8	54.3	11.5	87.0	22.9	163.9	36.7
Baitadi	Rato marso	Intermittent	4	39	2.9	68.1	52.7	10.2	129.4	25.9	203.2	49.6
Baitadi	Rato marso	Intermittent	5	35	3.0	69.2	48.8	9.7	146.5	31.5	209.1	60.5
Baitadi	Rato marso	Drought	1	10.8	3.0	73.7	50.7	10.8	64.2	12.0	143.1	48.4
Baitadi	Rato marso	Drought	2	24	3.1	74.2	48.9	9.8	47.5	13.6	120.0	35.6
Baitadi	Rato marso	Drought	3	19.8	2.8	69.3	46.4	9.8	52.2	11.5	131.8	33.1
Baitadi	Rato marso	Drought	4	13.4	2.9	68.3	50.7	13.6	46.4	14.8	132.5	39.8
Baitadi	Rato marso	Drought	5	15.4	3.0	67.9	48.1	12.1	84.5	17.9	146.3	35.2
Kanchanpur	Sauthyari	Control	1	68	11.3	146.0	71.0	17.8	65.3	24.1	634.5	223.4
Kanchanpur	Sauthyari	Control	2	74	11.0	91.9	70.3	17.5	96.7	26.9	910.3	264.8
Kanchanpur	Sauthyari	Control	3	75	11.6	101.0	76.3	19.1	74.4	18.8	843.5	222.5
Kanchanpur	Sauthyari	Control	4	100	9.4	97.1	72.4	18.1	96.5	22.1	795.4	243.1
Kanchanpur	Sauthyari	Control	5	72	9.8	83.1	61.1	15.3	140.4	26.6	769.5	273.9
Kanchanpur	Sauthyari	Intermittent	1	44	11.0	74.9	71.9	14.2	32.7	7.6	1596.7	497.1
Kanchanpur	Sauthyari	Intermittent	2	64	9.7	76.3	63.3	14.4	64.9	23.5	1112.2	279.6
Kanchanpur	Sauthyari	Intermittent	3	81	10.7	87.0	66.5	16.3	142.1	41.3	973.1	257.2
Kanchanpur	Sauthyari	Intermittent	4	81	11.4	81.6	70.8	15.5	45.2	24.6	753.7	231.5
Kanchanpur	Sauthyari	Intermittent	5	70	9.1	76.3	66.9	14.3	47.2	19.6	846.6	240.6
Kanchanpur	Sauthyari	Drought	1	29	9.3	97.3	56.8	18.0	91.2	26.6	544.5	195.7
Kanchanpur	Sauthyari	Drought	2	37	8.8	84.8	58.5	15.8	164.1	36.9	927.5	277.1
Kanchanpur	Sauthyari	Drought	3	39	10.3	94.1	64.6	16.6	82.7	20.8	873.3	269.3
Kanchanpur	Sauthyari	Drought	4	30	8.4	95.4	62.8	17.7	124.7	29.6	712.8	225.5
Kanchanpur	Sauthyari	Drought	5	35	10.7	88.8	57.5	16.7	84.9	28.7	813.3	273.5
Dadeldhura	Shanti	Control	1	32	5.4	93.6	70.5	8.8	93.6	40.7	792.1	195.7
Dadeldhura	Shanti	Control	2	26	4.4	84.5	61.6	9.6	115.9	39.3	457.3	144.5
Dadeldhura	Shanti	Control	3	83	5.3	103.0	75.4	8.9	168.3	69.2	448.9	158.7
Dadeldhura	Shanti	Control	4	11.8	5.2	79.9	53.1	9.2	141.6	54.3	575.7	176.5
Dadeldhura	Shanti	Control	5	39.8	5.8	85.9	62.5	9.5	144.6	59.6	636.5	180.0
Dadeldhura	Shanti	Intermittent	1	11	4.3	89.2	68.0	8.7	65.7	30.7	570.0	150.4
Dadeldhura	Shanti	Intermittent	2	12	4.6	91.0	76.1	7.7	143.5	65.3	467.9	169.8
Dadeldhura	Shanti	Intermittent	3	15.8	4.4	87.9	65.5	7.9	124.4	43.2	521.6	163.4
Dadeldhura	Shanti	Intermittent	4	23.4	4.4	92.4	61.0	9.0	126.2	49.8	467.0	156.7
Dadeldhura	Shanti	Intermittent	5	17	3.8	94.4	54.2	8.6	141.2	55.4	431.3	125.6
Dadeldhura	Shanti	Drought	1	10	5.0	94.1	66.6	8.7	74.3	29.8	546.0	165.7
Dadeldhura	Shanti	Drought	2	10	3.9	86.7	60.9	11.1	87.6	34.5	377.7	132.3
Dadeldhura	Shanti	Drought	3	21.8	4.9	93.2	59.2	8.8	180.6	60.5	484.6	134.7
Dadeldhura	Shanti	Drought	4	12.6	4.0	88.3	50.4	7.2	123.6	50.2	386.9	123.4
Dadeldhura	Shanti	Drought	5	15	4.8	82.7	51.1	8.8	102.3	45.6	407.7	105.2
Baitadi	Temase	Control	1	75.8	3.1	67.8	52.2	11.9	115.7	26.1	155.9	39.1
Baitadi	Temase	Control	2	95.2	2.9	64.8	51.4	12.1	82.1	23.5	166.5	34.1
Baitadi	Temase	Control	3	94.2	3.1	61.4	50.8	12.3	94.3	31.1	130.4	28.2

Baitadi	Temase	Control	4	87	2.8	68.7	48.3	10.6	95.8	21.3	175.5	49.0
Baitadi	Temase	Control	5	71	3.1	69.6	54.6	9.3	81.4	22.3	206.9	39.7
Baitadi	Temase	Intermittent	1	63	2.7	72.2	47.3	11.1	97.9	27.7	172.2	52.9
Baitadi	Temase	Intermittent	2	42	2.7	74.0	52.4	12.6	86.4	25.6	178.1	47.4
Baitadi	Temase	Intermittent	3	38	2.8	69.4	51.1	10.2	131.4	25.7	164.1	38.4
Baitadi	Temase	Intermittent	4	42	2.9	71.0	49.9	9.4	118.0	26.9	180.5	41.6
Baitadi	Temase	Intermittent	5	26.6	2.8	72.1	50.8	9.4	82.2	21.7	206.9	62.5
Baitadi	Temase	Drought	1	23.2	2.9	68.8	53.7	9.8	109.7	21.1	186.9	44.9
Baitadi	Temase	Drought	2	39.4	3.1	67.1	58.6	10.6	44.5	22.2	186.0	51.7
Baitadi	Temase	Drought	3	15.6	2.7	67.1	48.7	11.7	36.9	13.1	147.8	38.2
Baitadi	Temase	Drought	4	16	2.6	70.1	48.8	11.3	60.1	18.1	174.6	46.8
Baitadi	Temase	Drought	5	14	2.7	68.2	52.1	10.8	67.6	17.4	144.7	42.1

Annex-3. Reproductive characters

[PL=Panicle length (cm), TG= number of total grains per panicle, FG=number of filled grains per panicle, NG= number of non-filled grains per panicle, 1000W= weight of 1000 grains (gram), Y=Yield (tons/hectare)]

Location	Variety	Treatment	Rep	PL	TG	FG	NG	1000W	Y
Kanchanpur	Anjana	Control	1	22	89	73	16	21	4.32
Kanchanpur	Anjana	Control	2	21	91	81	10	20	4.48
Kanchanpur	Anjana	Control	3	23	116	93	23	20	5.33
Kanchanpur	Anjana	Control	4	23	98	83	15	19	4.79
Kanchanpur	Anjana	Control	5	21	109	86	23	22	5.56
Kanchanpur	Anjana	Intermittent	1	21	83	63	21	21	3.56
Kanchanpur	Anjana	Intermittent	2	23	98	87	10	21	4.70
Kanchanpur	Anjana	Intermittent	3	23	86	75	11	20	3.69
Kanchanpur	Anjana	Intermittent	4	20	90	72	18	21	3.96
Kanchanpur	Anjana	Intermittent	5	22	73	66	7	22	3.45
Kanchanpur	Anjana	Drought	1	23	91	68	23	20	3.69
Kanchanpur	Anjana	Drought	2	23	87	73	13	21	3.94
Kanchanpur	Anjana	Drought	3	25	85	56	29	18	2.85
Kanchanpur	Anjana	Drought	4	22	96	78	17	21	4.34
Kanchanpur	Anjana	Drought	5	20	96	76	20	20	4.03
Dadeldhura	Batebudo	Control	1	19	212	177	35	21	7.81
Dadeldhura	Batebudo	Control	2	18	151	127	24	20	5.26
Dadeldhura	Batebudo	Control	3	19	154	126	29	20	5.37
Dadeldhura	Batebudo	Control	4	19	184	169	15	21	7.25
Dadeldhura	Batebudo	Control	5	19	187	165	22	15	7.39
Dadeldhura	Batebudo	Intermittent	1	18	184	169	16	21	5.55
Dadeldhura	Batebudo	Intermittent	2	18	186	165	20	20	5.64
Dadeldhura	Batebudo	Intermittent	3	18	165	121	43	16	4.24
Dadeldhura	Batebudo	Intermittent	4	17	189	145	44	20	4.64
Dadeldhura	Batebudo	Intermittent	5	18	173	154	19	22	5.16
Dadeldhura	Batebudo	Drought	1	18	149	107	42	21	3.78
Dadeldhura	Batebudo	Drought	2	18	150	110	40	18	3.81
Dadeldhura	Batebudo	Drought	3	19	167	97	70	20	3.59
Dadeldhura	Batebudo	Drought	4	20	98	74	24	21	3.20
Dadeldhura	Batebudo	Drought	5	18	151	97	54	20	3.26
Baitadi	Chamade	Control	1	15	63	43	20	23	3.51
Baitadi	Chamade	Control	2	15	67	51	16	23	3.62
Baitadi	Chamade	Control	3	16	59	39	20	25	5.26
Baitadi	Chamade	Control	4	16	84	59	25	23	4.67
Baitadi	Chamade	Control	5	16	74	53	20	23	3.70
Baitadi	Chamade	Intermittent	1	16	66	52	14	20	3.21
Baitadi	Chamade	Intermittent	2	16	71	55	16	24	3.64
Baitadi	Chamade	Intermittent	3	14	75	55	20	22	3.31
Baitadi	Chamade	Intermittent	4	15	84	57	27	24	4.83

Baitadi	Chamade	Intermittent	5	12	60	49	12	22	3.70
Baitadi	Chamade	Drought	1	16	73	60	13	24	4.02
Baitadi	Chamade	Drought	2	16	65	34	31	24	4.29
Baitadi	Chamade	Drought	3	16	54	41	13	24	2.45
Baitadi	Chamade	Drought	4	16	70	51	19	24	3.52
Baitadi	Chamade	Drought	5	16	57	46	11	23	2.85
Dadeldhura	Chiudi	Control	1	16	103	93	11	32	4.32
Dadeldhura	Chiudi	Control	2	18	82	67	15	33	3.24
Dadeldhura	Chiudi	Control	3	17	71	59	12	35	2.74
Dadeldhura	Chiudi	Control	4	16	94	86	8	31	3.90
Dadeldhura	Chiudi	Control	5	17	94	85	9	29	3.67
Dadeldhura	Chiudi	Intermittent	1	17	112	103	9	30	4.52
Dadeldhura	Chiudi	Intermittent	2	17	93	86	7	30	3.73
Dadeldhura	Chiudi	Intermittent	3	16	87	81	6	29	3.45
Dadeldhura	Chiudi	Intermittent	4	15	86	61	25	32	3.01
Dadeldhura	Chiudi	Intermittent	5	16	89	51	38	35	3.10
Dadeldhura	Chiudi	Drought	1	16	55	37	19	30	1.22
Dadeldhura	Chiudi	Drought	2	15	61	47	14	31	1.46
Dadeldhura	Chiudi	Drought	3	16	70	47	23	27	1.45
Dadeldhura	Chiudi	Drought	4	17	91	62	29	27	1.94
Dadeldhura	Chiudi	Drought	5	16	87	67	20	28	1.95
Kanchanpur	Ghiupuri	Control	1	25	99	66	33	14	2.74
Kanchanpur	Ghiupuri	Control	2	24	133	109	24	13	3.97
Kanchanpur	Ghiupuri	Control	3	23	97	74	23	13	2.90
Kanchanpur	Ghiupuri	Control	4	25	124	106	19	13	3.72
Kanchanpur	Ghiupuri	Control	5	25	128	107	21	13	3.63
Kanchanpur	Ghiupuri	Intermittent	1	23	85	66	19	13	2.54
Kanchanpur	Ghiupuri	Intermittent	2	19	121	97	24	13	3.41
Kanchanpur	Ghiupuri	Intermittent	3	24	102	77	24	14	2.84
Kanchanpur	Ghiupuri	Intermittent	4	21	78	52	26	15	2.16
Kanchanpur	Ghiupuri	Intermittent	5	21	99	73	26	14	2.62
Kanchanpur	Ghiupuri	Drought	1	24	123	95	28	14	3.32
Kanchanpur	Ghiupuri	Drought	2	22	119	77	42	15	3.01
Kanchanpur	Ghiupuri	Drought	3	25	103	83	21	14	2.95
Kanchanpur	Ghiupuri	Drought	4	24	149	106	44	13	3.61
Kanchanpur	Ghiupuri	Drought	5	22	110	87	23	15	3.25
Dadeldhura	Jhini	Control	1	24	230	209	21	17	4.34
Dadeldhura	Jhini	Control	2	24	159	145	15	17	3.02
Dadeldhura	Jhini	Control	3	23	185	172	14	17	3.51
Dadeldhura	Jhini	Control	4	23	180	167	13	17	3.54
Dadeldhura	Jhini	Control	5	23	148	120	29	17	2.52
Dadeldhura	Jhini	Intermittent	1	25	206	187	19	18	2.89
Dadeldhura	Jhini	Intermittent	2	24	153	127	26	6	1.86

Dadeldhura	Jhini	Intermittent	3	24	168	149	18	16	2.23
Dadeldhura	Jhini	Intermittent	4	22	171	150	21	16	2.20
Dadeldhura	Jhini	Intermittent	5	24	148	114	34	16	1.66
Dadeldhura	Jhini	Drought	1	25	141	83	59	15	1.23
Dadeldhura	Jhini	Drought	2	25	88	56	31	16	0.84
Dadeldhura	Jhini	Drought	3	24	144	108	36	16	1.56
Dadeldhura	Jhini	Drought	4	27	107	53	54	16	1.18
Dadeldhura	Jhini	Drought	5	25	120	47	73	16	1.19
Baitadi	Jhumke	Control	1	29	85	62	23	26	6.09
Baitadi	Jhumke	Control	2	25	85	48	36	23	5.78
Baitadi	Jhumke	Control	3	27	74	49	24	25	6.37
Baitadi	Jhumke	Control	4	26	78	47	31	23	4.31
Baitadi	Jhumke	Control	5	24	71	45	25	24	4.54
Baitadi	Jhumke	Intermittent	1	25	67	42	25	23	3.37
Baitadi	Jhumke	Intermittent	2	25	73	47	26	24	3.41
Baitadi	Jhumke	Intermittent	3	25	49	31	18	25	3.06
Baitadi	Jhumke	Intermittent	4	25	62	40	22	27	4.61
Baitadi	Jhumke	Intermittent	5	26	144	75	69	24	7.04
Baitadi	Jhumke	Drought	1	28	25	20	5	18	1.57
Baitadi	Jhumke	Drought	2	25	67	42	25	24	3.09
Baitadi	Jhumke	Drought	3	25	82	50	33	24	5.00
Baitadi	Jhumke	Drought	4	27	73	46	27	25	4.60
Baitadi	Jhumke	Drought	5	25	66	43	23	25	4.45
Kanchanpur	Lalchand	Control	1	25	104	63	41	20	3.97
Kanchanpur	Lalchand	Control	2	23	97	80	16	22	5.00
Kanchanpur	Lalchand	Control	3	24	68	52	16	21	3.07
Kanchanpur	Lalchand	Control	4	24	75	60	15	23	4.22
Kanchanpur	Lalchand	Control	5	24	68	49	19	21	3.08
Kanchanpur	Lalchand	Intermittent	1	23	83	61	21	22	3.38
Kanchanpur	Lalchand	Intermittent	2	21	65	57	8	20	2.78
Kanchanpur	Lalchand	Intermittent	3	21	89	74	15	23	3.56
Kanchanpur	Lalchand	Intermittent	4	20	71	47	24	27	3.17
Kanchanpur	Lalchand	Intermittent	5	21	70	49	21	22	2.82
Kanchanpur	Lalchand	Drought	1	24	77	63	14	21	3.62
Kanchanpur	Lalchand	Drought	2	20	79	60	19	21	3.35
Kanchanpur	Lalchand	Drought	3	23	73	62	10	22	3.74
Kanchanpur	Lalchand	Drought	4	23	89	69	19	21	4.08
Kanchanpur	Lalchand	Drought	5	21	59	47	11	21	2.69
Baitadi	Rato marso	Control	1	29	44	33	11	26	2.91
Baitadi	Rato marso	Control	2	27	42	32	10	27	2.97
Baitadi	Rato marso	Control	3	27	71	58	13	25	3.99
Baitadi	Rato marso	Control	4	28	61	44	18	24	2.84
Baitadi	Rato marso	Control	5	28	49	39	10	26	2.06

Baitadi	Rato marso	Intermittent	1	26	55	41	14	25	2.60
Baitadi	Rato marso	Intermittent	2	24	39	30	9	25	1.90
Baitadi	Rato marso	Intermittent	3	26	53	40	13	25	2.55
Baitadi	Rato marso	Intermittent	4	24	54	46	7	25	2.70
Baitadi	Rato marso	Intermittent	5	24	43	37	6	28	2.29
Baitadi	Rato marso	Drought	1	27	33	26	8	25	1.45
Baitadi	Rato marso	Drought	2	26	41	29	12	25	1.62
Baitadi	Rato marso	Drought	3	27	48	25	23	25	1.53
Baitadi	Rato marso	Drought	4	27	43	32	10	25	2.00
Baitadi	Rato marso	Drought	5	25	33	27	6	25	1.51
Kanchanpur	Sauthyari	Control	1	27	76	51	25	22	5.62
Kanchanpur	Sauthyari	Control	2	25	73	62	11	23	6.75
Kanchanpur	Sauthyari	Control	3	25	51	41	10	24	4.89
Kanchanpur	Sauthyari	Control	4	26	70	51	19	22	5.27
Kanchanpur	Sauthyari	Control	5	25	77	52	25	23	5.84
Kanchanpur	Sauthyari	Intermittent	1	25	85	65	20	23	6.31
Kanchanpur	Sauthyari	Intermittent	2	24	97	58	38	24	5.95
Kanchanpur	Sauthyari	Intermittent	3	23	74	57	18	22	5.35
Kanchanpur	Sauthyari	Intermittent	4	23	55	35	20	23	3.48
Kanchanpur	Sauthyari	Intermittent	5	23	67	53	14	22	4.98
Kanchanpur	Sauthyari	Drought	1	26	85	45	40	22	5.67
Kanchanpur	Sauthyari	Drought	2	22	70	58	12	21	5.73
Kanchanpur	Sauthyari	Drought	3	24	75	56	19	23	5.68
Kanchanpur	Sauthyari	Drought	4	24	50	36	14	23	4.05
Kanchanpur	Sauthyari	Drought	5	24	91	76	14	25	5.73
Dadeldhura	Shanti	Control	1	26	154	138	17	18	3.33
Dadeldhura	Shanti	Control	2	25	130	116	14	16	2.75
Dadeldhura	Shanti	Control	3	25	126	95	31	16	2.14
Dadeldhura	Shanti	Control	4	27	140	130	10	18	3.25
Dadeldhura	Shanti	Control	5	26	137	120	18	18	2.95
Dadeldhura	Shanti	Intermittent	1	25	135	88	47	18	2.00
Dadeldhura	Shanti	Intermittent	2	24	114	56	58	16	1.35
Dadeldhura	Shanti	Intermittent	3	24	94	72	22	20	1.97
Dadeldhura	Shanti	Intermittent	4	23	125	85	40	16	1.90
Dadeldhura	Shanti	Intermittent	5	26	95	65	30	18	1.72
Dadeldhura	Shanti	Drought	1	26	109	75	34	21	2.05
Dadeldhura	Shanti	Drought	2	24	104	48	57	16	1.13
Dadeldhura	Shanti	Drought	3	25	97	54	42	14	1.06
Dadeldhura	Shanti	Drought	4	26	89	58	31	16	1.27
Dadeldhura	Shanti	Drought	5	25	99	71	28	17	1.43
Baitadi	Temase	Control	1	29	84	66	18	25	2.34
Baitadi	Temase	Control	2	27	51	42	9	26	3.41
Baitadi	Temase	Control	3	27	50	28	22	26	2.32

Baitadi	Temase	Control	4	28	59	49	10	24	3.83
Baitadi	Temase	Control	5	28	64	52	11	24	4.16
Baitadi	Temase	Intermittent	1	26	34	31	3	22	2.90
Baitadi	Temase	Intermittent	2	24	54	44	9	24	2.14
Baitadi	Temase	Intermittent	3	26	39	34	6	23	1.99
Baitadi	Temase	Intermittent	4	25	62	52	9	25	2.56
Baitadi	Temase	Intermittent	5	24	49	42	7	24	3.04
Baitadi	Temase	Drought	1	27	45	41	3	23	2.40
Baitadi	Temase	Drought	2	26	53	39	13	23	1.99
Baitadi	Temase	Drought	3	28	44	36	8	24	1.82
Baitadi	Temase	Drought	4	27	47	39	8	24	1.76
Baitadi	Temase	Drought	5	25	51	41	10	24	2.13

Annex-4. Biochemical parameters

[F_cha= chlorophyll a at the time of flowering (µg/g FW), F_clb= chlorophyll b at the time of flowering (µg/g FW), F_car= carotenoid content in the leaf at the time of flowering (µg/g FW), F_tc = Total Chlorophyll content at the time of flowering (µg/g FW), H_cha= chlorophyll a in the leaf at the time of harvesting (µg/g FW), H_clb= chlorophyll b at the time of harvesting (µg/g FW), H_car= carotenoid content in the leaf at the time of harvesting (µg/g FW), H_tc = Total Chlorophyll content at the time of harvesting (µg/g FW), CA= catalase activity (units/min/g FW)]

Location	Variety	Treatment	Rep	F_cha	F_chb	F_car	F_tc	H_cha	H_chb	H_car	H_tc	CA
Kanchanpur	Anjana	Control	1	0.85	1.00	0.25	1.86	0.72	0.63	0.37	1.35	38.68
Kanchanpur	Anjana	Control	2	0.69	1.12	0.44	1.80	1.30	1.16	0.59	2.46	48.71
Kanchanpur	Anjana	Control	3	0.09	0.03	0.04	0.12	1.38	1.02	0.56	2.40	47.28
Kanchanpur	Anjana	Control	4	0.07	0.02	0.03	0.09	1.65	1.33	0.50	2.98	53.01
Kanchanpur	Anjana	Control	5	0.08	0.03	0.04	0.11	0.88	0.58	0.37	1.46	45.85
Kanchanpur	Anjana	Intermittent	1	0.55	0.98	0.51	1.53	1.23	0.73	0.50	1.97	47.28
Kanchanpur	Anjana	Intermittent	2	0.12	0.04	0.05	0.16	1.40	1.01	0.50	2.41	48.71
Kanchanpur	Anjana	Intermittent	3	0.09	0.03	0.04	0.12	1.05	0.59	0.34	1.64	50.14
Kanchanpur	Anjana	Intermittent	4	0.09	0.05	0.05	0.14	1.00	0.73	0.45	1.73	51.58
Kanchanpur	Anjana	Intermittent	5	0.11	0.05	0.05	0.16	0.95	0.62	0.39	1.56	51.58
Kanchanpur	Anjana	Drought	1	0.79	0.74	0.19	1.53	1.27	0.80	0.46	2.07	53.01
Kanchanpur	Anjana	Drought	2	0.81	0.61	0.37	1.42	0.80	0.57	0.39	1.38	53.01
Kanchanpur	Anjana	Drought	3	0.07	0.04	0.04	0.10	1.57	1.15	0.50	2.72	60.17
Kanchanpur	Anjana	Drought	4	0.06	0.04	0.04	0.10	1.11	0.85	0.58	1.97	64.47
Kanchanpur	Anjana	Drought	5	0.07	0.05	0.05	0.12	1.43	0.91	0.53	2.35	63.04
Dadeldhura	Batebudo	Control	1	2.90	2.16	0.69	5.06	0.49	0.46	0.57	0.95	51.58
Dadeldhura	Batebudo	Control	2	2.58	2.12	0.77	4.70	0.26	0.41	0.31	0.67	54.44
Dadeldhura	Batebudo	Control	3	0.94	1.58	0.36	2.52	0.54	0.46	0.42	1.01	51.58
Dadeldhura	Batebudo	Control	4	1.56	2.23	0.54	3.78	0.40	0.35	0.35	0.75	54.44
Dadeldhura	Batebudo	Control	5	2.30	1.42	0.62	3.72	0.61	0.44	0.44	1.05	58.74
Dadeldhura	Batebudo	Intermittent	1	1.29	2.06	0.56	3.35	0.57	0.47	0.36	1.04	55.87
Dadeldhura	Batebudo	Intermittent	2	2.24	1.85	0.56	4.09	0.90	0.41	0.48	1.31	58.74
Dadeldhura	Batebudo	Intermittent	3	2.42	2.29	0.74	4.71	0.58	0.67	0.33	1.25	53.01
Dadeldhura	Batebudo	Intermittent	4	2.40	2.12	0.78	4.52	0.62	0.73	0.49	1.35	58.74
Dadeldhura	Batebudo	Intermittent	5	0.42	0.71	0.29	1.13	0.28	0.46	0.23	0.74	54.44
Dadeldhura	Batebudo	Drought	1	2.65	2.01	0.87	4.66	0.46	0.55	0.31	1.01	60.17
Dadeldhura	Batebudo	Drought	2	0.42	0.43	0.21	0.85	0.32	0.32	0.24	0.64	63.04
Dadeldhura	Batebudo	Drought	3	0.59	0.73	0.48	1.32	0.17	0.24	0.16	0.41	61.60
Dadeldhura	Batebudo	Drought	4	0.55	1.01	0.51	1.56	0.70	0.97	0.25	1.67	55.87
Dadeldhura	Batebudo	Drought	5	1.15	1.86	0.50	3.01	0.25	0.69	0.16	0.94	61.60
Baitadi	Chamade	Control	1	2.52	1.39	0.98	3.92	0.41	0.45	0.25	0.86	80.23
Baitadi	Chamade	Control	2	1.81	0.89	0.61	2.70	0.92	0.93	0.61	1.84	78.80
Baitadi	Chamade	Control	3	2.18	1.19	0.61	3.37	0.22	0.27	0.38	0.49	77.36
Baitadi	Chamade	Control	4	2.72	1.99	0.48	4.71	0.50	0.45	0.34	0.95	77.36
Baitadi	Chamade	Control	5	2.73	1.97	0.58	4.70	0.66	0.67	0.40	1.33	75.93
Baitadi	Chamade	Intermittent	1	2.65	1.79	0.50	4.45	0.68	0.61	0.44	1.29	88.83
Baitadi	Chamade	Intermittent	2	2.83	2.04	0.53	4.87	0.74	0.69	0.49	1.43	84.53

Baitadi	Chamade	Intermittent	3	2.98	2.06	0.48	5.03	0.59	0.52	0.44	1.11	85.96
Baitadi	Chamade	Intermittent	4	2.50	1.73	0.46	4.23	0.16	0.18	0.39	0.34	80.23
Baitadi	Chamade	Intermittent	5	3.09	2.14	0.47	5.23	0.59	0.53	0.43	1.12	83.09
Baitadi	Chamade	Drought	1	1.61	1.36	0.18	2.97	0.17	0.23	0.29	0.39	84.53
Baitadi	Chamade	Drought	2	2.73	1.79	0.47	4.52	0.07	0.11	0.09	0.19	81.66
Baitadi	Chamade	Drought	3	2.31	1.12	0.63	3.43	0.66	0.61	0.48	1.27	80.23
Baitadi	Chamade	Drought	4	2.16	0.92	0.65	3.08	0.65	0.52	0.44	1.17	87.39
Baitadi	Chamade	Drought	5	1.10	0.74	0.13	1.84	0.15	0.22	0.50	0.37	87.39
Dadeldhura	Chiudi	Control	1	2.23	1.76	0.46	3.99	2.00	1.13	0.31	3.13	55.87
Dadeldhura	Chiudi	Control	2	2.40	1.56	0.49	3.96	1.87	0.88	0.41	2.75	54.44
Dadeldhura	Chiudi	Control	3	2.42	1.84	0.45	4.26	1.53	0.68	0.42	2.21	58.74
Dadeldhura	Chiudi	Control	4	2.11	1.51	0.40	3.62	1.42	0.59	0.42	2.02	54.44
Dadeldhura	Chiudi	Control	5	2.36	1.58	0.43	3.93	1.53	0.67	0.43	2.20	57.31
Dadeldhura	Chiudi	Intermittent	1	1.54	1.37	0.14	2.91	1.34	0.53	0.42	1.87	50.14
Dadeldhura	Chiudi	Intermittent	2	2.15	1.44	0.36	3.59	0.93	0.41	0.31	1.34	55.87
Dadeldhura	Chiudi	Intermittent	3	2.43	1.60	0.44	4.04	2.44	1.90	-0.04	4.34	55.87
Dadeldhura	Chiudi	Intermittent	4	2.37	1.50	0.38	3.87	1.15	0.49	0.40	1.64	58.74
Dadeldhura	Chiudi	Intermittent	5	2.74	1.89	0.50	4.63	1.11	0.49	0.42	1.60	60.17
Dadeldhura	Chiudi	Drought	1	1.90	1.26	0.42	3.16	1.55	0.64	0.40	2.19	61.60
Dadeldhura	Chiudi	Drought	2	1.05	0.94	0.31	1.99	1.79	0.88	0.40	2.67	57.31
Dadeldhura	Chiudi	Drought	3	2.39	1.48	0.48	3.87	1.73	0.76	0.42	2.50	60.17
Dadeldhura	Chiudi	Drought	4	2.41	1.58	0.49	3.99	1.13	0.55	0.43	1.68	61.60
Dadeldhura	Chiudi	Drought	5	2.07	1.93	0.51	4.00	2.19	1.16	0.24	3.36	58.74
Kanchanpur	Ghiupuri	Control	1	0.42	0.56	0.29	0.98	1.93	1.30	0.37	3.23	44.41
Kanchanpur	Ghiupuri	Control	2	1.05	1.14	0.40	2.18	2.39	1.84	0.11	4.23	35.82
Kanchanpur	Ghiupuri	Control	3	0.07	0.04	0.04	0.11	1.05	0.48	0.28	1.53	51.58
Kanchanpur	Ghiupuri	Control	4	0.13	0.08	0.08	0.21	2.37	1.65	0.05	4.01	41.55
Kanchanpur	Ghiupuri	Control	5	0.06	0.05	0.05	0.11	1.63	0.88	0.40	2.51	42.98
Kanchanpur	Ghiupuri	Intermittent	1	0.81	1.59	0.26	2.41	1.56	0.75	0.41	2.32	44.41
Kanchanpur	Ghiupuri	Intermittent	2	1.16	1.09	0.18	2.25	1.85	1.04	0.36	2.89	50.14
Kanchanpur	Ghiupuri	Intermittent	3	0.09	0.05	0.05	0.13	1.59	0.82	0.41	2.41	48.71
Kanchanpur	Ghiupuri	Intermittent	4	0.07	0.04	0.04	0.11	1.14	0.61	0.37	1.75	50.14
Kanchanpur	Ghiupuri	Intermittent	5	0.05	0.30	0.04	0.35	1.46	0.77	0.41	2.24	45.85
Kanchanpur	Ghiupuri	Drought	1	0.58	0.84	0.70	1.42	1.79	0.90	0.33	2.69	53.01
Kanchanpur	Ghiupuri	Drought	2	0.97	0.56	0.18	1.53	1.18	0.51	0.40	1.68	58.74
Kanchanpur	Ghiupuri	Drought	3	0.09	0.06	0.06	0.15	0.91	0.47	0.28	1.38	54.44
Kanchanpur	Ghiupuri	Drought	4	0.09	0.06	0.06	0.15	0.60	0.33	0.20	0.93	51.58
Kanchanpur	Ghiupuri	Drought	5	0.06	0.12	0.03	0.18	1.06	0.65	0.49	1.71	54.44
Dadeldhura	Jhini	Control	1	1.05	1.00	0.10	2.05	1.15	0.52	0.30	1.67	57.31
Dadeldhura	Jhini	Control	2	2.13	1.56	0.34	3.69	1.34	0.58	0.41	1.92	58.74
Dadeldhura	Jhini	Control	3	2.52	1.43	0.53	3.95	1.52	0.65	0.49	2.17	55.87
Dadeldhura	Jhini	Control	4	2.80	1.87	0.50	4.67	1.27	0.55	0.42	1.82	57.31
Dadeldhura	Jhini	Control	5	1.42	1.28	0.13	2.69	0.69	0.30	0.27	0.99	55.87

Dadeldhura	Jhini	Intermittent	1	1.96	1.39	0.30	3.34	1.77	0.74	0.38	2.51	64.47
Dadeldhura	Jhini	Intermittent	2	1.30	1.17	0.12	2.47	1.36	0.58	0.35	1.94	64.47
Dadeldhura	Jhini	Intermittent	3	3.05	1.76	0.59	4.80	0.56	0.25	0.26	0.81	58.74
Dadeldhura	Jhini	Intermittent	4	3.14	2.04	0.50	5.19	0.91	0.39	0.30	1.30	61.60
Dadeldhura	Jhini	Intermittent	5	0.99	1.04	0.17	2.03	1.08	0.50	0.34	1.58	55.87
Dadeldhura	Jhini	Drought	1	1.85	1.58	0.66	3.42	0.92	0.45	0.36	1.37	60.17
Dadeldhura	Jhini	Drought	2	0.80	1.05	0.06	1.85	1.42	0.67	0.43	2.08	68.77
Dadeldhura	Jhini	Drought	3	2.17	1.95	0.81	4.12	1.64	0.73	0.43	2.37	74.50
Dadeldhura	Jhini	Drought	4	1.31	1.27	0.21	2.58	2.14	1.06	0.28	3.20	68.77
Dadeldhura	Jhini	Drought	5	1.94	1.31	0.76	3.25	1.95	0.92	0.35	2.86	63.04
Baitadi	Jhumke	Control	1	1.67	0.87	0.39	2.54	0.30	0.25	0.28	0.55	68.77
Baitadi	Jhumke	Control	2	2.39	1.30	0.54	3.69	1.68	1.36	0.46	3.04	67.34
Baitadi	Jhumke	Control	3	1.71	0.91	0.35	2.62	1.61	1.36	0.42	2.98	64.47
Baitadi	Jhumke	Control	4	3.49	1.83	0.63	5.33	0.32	0.29	0.44	0.60	64.47
Baitadi	Jhumke	Control	5	1.47	0.86	0.33	2.33	1.10	1.07	0.71	2.17	65.90
Baitadi	Jhumke	Intermittent	1	1.09	0.61	0.26	1.70	0.95	0.60	0.47	1.54	68.77
Baitadi	Jhumke	Intermittent	2	1.85	1.02	0.54	2.86	1.72	1.02	0.35	2.75	65.90
Baitadi	Jhumke	Intermittent	3	1.44	0.82	0.33	2.26	0.62	0.45	0.45	1.07	70.20
Baitadi	Jhumke	Intermittent	4	2.00	1.29	0.44	3.29	1.10	0.93	0.53	2.03	68.77
Baitadi	Jhumke	Intermittent	5	1.77	0.86	0.41	2.63	0.89	0.59	0.39	1.48	71.63
Baitadi	Jhumke	Drought	1	2.12	1.00	0.62	3.13	0.73	0.46	0.36	1.19	80.23
Baitadi	Jhumke	Drought	2	2.20	1.20	0.62	3.40	1.19	0.75	0.46	1.93	70.20
Baitadi	Jhumke	Drought	3	2.03	1.18	0.61	3.22	1.36	1.10	0.48	2.45	74.50
Baitadi	Jhumke	Drought	4	2.06	0.97	0.65	3.03	0.96	0.75	0.46	1.71	75.93
Baitadi	Jhumke	Drought	5	2.21	1.00	0.54	3.20	0.22	0.21	0.40	0.43	73.07
Kanchanpur	Lalchand	Control	1	1.17	1.44	0.39	2.60	1.53	1.06	0.42	2.59	38.68
Kanchanpur	Lalchand	Control	2	0.84	1.08	0.25	1.92	1.62	1.61	0.47	3.23	47.28
Kanchanpur	Lalchand	Control	3	0.11	0.05	0.08	0.16	0.89	0.64	0.31	1.53	48.71
Kanchanpur	Lalchand	Control	4	0.11	0.05	0.07	0.16	1.40	0.99	0.48	2.39	42.98
Kanchanpur	Lalchand	Control	5	0.17	0.06	0.08	0.23	0.91	0.65	0.30	1.56	45.85
Kanchanpur	Lalchand	Intermittent	1	0.67	1.18	0.49	1.85	1.80	1.09	0.37	2.89	51.58
Kanchanpur	Lalchand	Intermittent	2	0.14	0.04	0.04	0.18	1.72	0.08	0.04	1.80	48.71
Kanchanpur	Lalchand	Intermittent	3	0.09	0.03	0.03	0.12	1.24	0.43	0.27	1.67	60.17
Kanchanpur	Lalchand	Intermittent	4	0.09	0.04	0.05	0.13	0.74	0.94	0.51	1.67	61.60
Kanchanpur	Lalchand	Intermittent	5	0.11	0.04	0.43	0.15	1.62	1.22	0.45	2.85	54.44
Kanchanpur	Lalchand	Drought	1	0.82	1.31	0.47	2.13	1.82	1.17	0.36	2.99	57.31
Kanchanpur	Lalchand	Drought	2	0.54	0.80	0.46	1.34	0.72	2.52	0.55	3.24	58.74
Kanchanpur	Lalchand	Drought	3	0.14	0.03	0.03	0.16	0.93	1.01	0.54	1.95	64.47
Kanchanpur	Lalchand	Drought	4	0.12	0.04	0.06	0.16	1.05	0.33	0.24	1.37	63.04
Kanchanpur	Lalchand	Drought	5	0.15	0.06	0.06	0.21	1.69	1.30	0.39	2.99	68.77
Baitadi	Rato marso	Control	1	1.43	0.86	0.27	2.29	0.22	0.17	0.16	0.39	61.60
Baitadi	Rato marso	Control	2	1.94	0.91	0.52	2.85	0.10	0.12	0.05	0.21	55.87
Baitadi	Rato marso	Control	3	2.14	1.08	0.50	3.22	0.08	0.11	0.05	0.19	55.87

Baitadi	Rato marso	Control	4	1.65	0.89	0.29	2.53	0.08	0.11	0.17	0.19	50.14
Baitadi	Rato marso	Control	5	1.62	0.81	0.41	2.43	0.08	0.10	0.25	0.18	60.17
Baitadi	Rato marso	Intermittent	1	1.13	0.59	0.32	1.72	0.75	0.45	0.26	1.20	63.04
Baitadi	Rato marso	Intermittent	2	0.93	0.44	0.22	1.37	0.38	0.23	0.23	0.62	61.60
Baitadi	Rato marso	Intermittent	3	1.42	0.69	0.40	2.11	0.73	0.38	0.37	1.12	63.04
Baitadi	Rato marso	Intermittent	4	1.08	0.64	0.34	1.72	0.46	0.27	0.34	0.72	65.90
Baitadi	Rato marso	Intermittent	5	1.09	0.63	0.33	1.72	1.08	0.49	0.33	1.57	64.47
Baitadi	Rato marso	Drought	1	1.46	0.90	0.35	2.35	0.09	0.13	0.03	0.22	70.20
Baitadi	Rato marso	Drought	2	1.79	0.89	0.39	2.68	0.21	0.16	0.18	0.37	70.20
Baitadi	Rato marso	Drought	3	1.88	0.90	0.51	2.78	0.20	0.23	0.21	0.43	68.77
Baitadi	Rato marso	Drought	4	2.07	0.95	0.45	3.02	0.34	0.29	0.46	0.63	68.77
Baitadi	Rato marso	Drought	5	1.72	0.78	0.45	2.50	0.40	0.31	0.53	0.71	68.77
Kanchanpur	Sauthyari	Control	1	1.11	1.32	0.21	2.43	0.67	0.74	0.30	1.41	53.01
Kanchanpur	Sauthyari	Control	2	0.82	0.76	0.38	1.58	1.15	1.19	0.58	2.34	35.82
Kanchanpur	Sauthyari	Control	3	0.09	0.03	0.03	0.12	1.17	1.18	0.52	2.35	47.28
Kanchanpur	Sauthyari	Control	4	0.11	0.04	0.05	0.15	1.29	1.17	0.52	2.46	45.85
Kanchanpur	Sauthyari	Control	5	0.10	0.04	0.05	0.13	0.59	0.53	0.22	1.11	44.41
Kanchanpur	Sauthyari	Intermittent	1	0.80	1.29	0.30	2.10	1.76	1.94	0.42	3.70	42.98
Kanchanpur	Sauthyari	Intermittent	2	0.09	0.03	0.04	0.12	1.07	0.91	0.49	1.98	47.28
Kanchanpur	Sauthyari	Intermittent	3	0.11	0.04	0.05	0.15	1.35	1.37	0.58	2.71	50.14
Kanchanpur	Sauthyari	Intermittent	4	0.13	0.05	0.06	0.18	1.19	1.15	0.52	2.34	37.25
Kanchanpur	Sauthyari	Intermittent	5	0.11	0.03	0.04	0.14	1.13	0.98	0.54	2.10	67.34
Kanchanpur	Sauthyari	Drought	1	1.31	1.31	0.47	2.62	0.85	0.89	0.44	1.74	61.60
Kanchanpur	Sauthyari	Drought	2	1.38	1.55	0.43	2.93	1.19	1.43	0.47	2.62	63.04
Kanchanpur	Sauthyari	Drought	3	0.53	0.78	0.26	1.31	1.33	1.40	0.58	2.73	65.90
Kanchanpur	Sauthyari	Drought	4	0.13	0.05	0.07	0.18	1.49	0.99	0.46	2.49	63.04
Kanchanpur	Sauthyari	Drought	5	0.08	0.03	0.03	0.11	1.42	0.87	0.41	2.29	60.17
Dadeldhura	Shanti	Control	1	3.05	1.95	0.45	5.00	0.96	0.76	0.67	1.72	47.28
Dadeldhura	Shanti	Control	2	3.26	2.01	0.52	5.27	1.30	0.69	0.48	1.99	53.01
Dadeldhura	Shanti	Control	3	2.96	1.73	0.53	4.69	0.72	0.73	0.30	1.44	67.34
Dadeldhura	Shanti	Control	4	2.80	1.60	0.50	4.40	1.22	0.97	0.35	2.19	58.74
Dadeldhura	Shanti	Control	5	2.79	1.75	0.50	4.54	0.90	0.86	0.44	1.76	60.17
Dadeldhura	Shanti	Intermittent	1	3.56	1.94	0.50	5.50	1.41	1.08	0.25	2.49	63.04
Dadeldhura	Shanti	Intermittent	2	2.78	1.47	0.56	4.24	1.15	0.73	0.36	1.88	48.71
Dadeldhura	Shanti	Intermittent	3	1.60	1.19	0.14	2.79	0.72	0.75	0.36	1.47	60.17
Dadeldhura	Shanti	Intermittent	4	3.42	1.72	0.62	5.14	0.06	0.12	0.02	0.18	58.74
Dadeldhura	Shanti	Intermittent	5	2.68	1.55	0.36	4.23	0.65	0.37	0.43	1.02	57.31
Dadeldhura	Shanti	Drought	1	2.29	1.63	0.33	3.92	0.86	0.78	0.38	1.64	58.74
Dadeldhura	Shanti	Drought	2	2.47	1.31	0.55	3.78	1.80	1.21	0.26	3.01	63.04
Dadeldhura	Shanti	Drought	3	3.03	1.84	0.57	4.87	0.51	0.51	0.31	1.02	64.47
Dadeldhura	Shanti	Drought	4	2.52	1.46	0.48	3.98	0.48	0.37	0.29	0.85	58.74
Dadeldhura	Shanti	Drought	5	3.08	1.82	0.48	4.90	0.19	0.15	0.45	0.34	58.74
Baitadi	Temase	Control	1	1.31	1.17	0.45	2.47	0.21	0.26	0.26	0.47	60.17

Baitadi	Temase	Control	2	1.36	1.06	0.42	2.42	0.75	0.62	0.51	1.37	53.01
Baitadi	Temase	Control	3	1.28	0.86	0.30	2.14	1.15	0.73	0.67	1.88	70.20
Baitadi	Temase	Control	4	1.41	1.09	0.29	2.50	0.30	0.29	0.25	0.59	50.14
Baitadi	Temase	Control	5	1.44	0.91	0.41	2.35	1.30	1.13	0.37	2.43	47.28
Baitadi	Temase	Intermittent	1	1.67	1.07	0.29	2.74	0.10	0.16	0.10	0.26	74.50
Baitadi	Temase	Intermittent	2	1.60	1.04	0.54	2.64	0.29	0.22	0.22	0.51	64.47
Baitadi	Temase	Intermittent	3	0.88	0.58	0.24	1.45	1.15	0.74	0.40	1.89	70.20
Baitadi	Temase	Intermittent	4	1.00	0.67	0.24	1.67	0.47	0.33	0.22	0.80	67.34
Baitadi	Temase	Intermittent	5	1.43	0.91	0.35	2.34	0.61	0.37	0.27	0.98	67.34
Baitadi	Temase	Drought	1	1.47	0.91	0.40	2.38	0.31	0.21	0.31	0.53	67.34
Baitadi	Temase	Drought	2	1.56	0.84	0.36	2.40	0.18	0.19	0.16	0.37	68.77
Baitadi	Temase	Drought	3	1.72	0.97	0.39	2.69	0.57	0.44	0.25	1.01	67.34
Baitadi	Temase	Drought	4	1.22	0.80	0.26	2.02	0.82	0.51	0.28	1.34	73.07
Baitadi	Temase	Drought	5	1.05	0.62	0.27	1.67	1.12	0.63	0.36	1.75	73.07

Annex-5 Photo plates