ISSN 2518–2021 (Print) 2415–4474 (Electronic)

Fundamental and Applied Agriculture

Journal home page: https://www.f2ffoundation.org/faa/index.php/home

Vol. 9(3), pp. 162 – 167: 2024, doi: https://doi.org/10.5455/faa.166603

Agronomy | ORIGINAL ARTICLE

Evaluation of Stable, and Adaptable Wheat Genotypes under Late Sown (Heat Stress) and Drought under Late Sown (Heat-Drought) Conditions

Shivalal Nyaupane[1]*; Radhakrishna Bhandari[2]; Mukti Ram Poudel[2]

[1]Institute of Agriculture and Animal Science (IAAS), Paklihawa Campus, Nepal
[2]Tribhuvan University, Bhairahawa, Rupandehi, Nepal

ARTICLE INFO

Article history
Received: 11 April 2024
Accepted: 29 June 2024
Published online: 30 Sept 2024

Keywords
Adaptability,
Biplots,
Drought,
Genotype × Environment Interaction,
Heat stress,
Stability

Correspondence
Shivalal Nyaupane
: lalshiva2000@gmail.com

ABSTRACT

Heat stress and drought are the major problems for wheat production. Heat stress and drought causes a significant yield reduction of wheat in Nepal. To evaluate the stability, and adaptability of wheat genotypes, a field experiment was conducted using 20 elite wheat genotypes at the Institute of Agriculture and Animal Science (IAAS), Paklihawa Campus, Nepal in an alpha lattice design with two replication. AMMI model revealed that environment had a significant effect on grain yield of wheat and explained 55.22% of the total variation in grain yield. Which-Won-Where model showed that NL 1404 and NL 1386 were the most stable genotypes across late sown and drought under late sown conditions whereas, NL 1368 and Bhirkuti were specifically adapted genotypes under late sown and drought under late sown conditions, respectively. Thus, these genotypes can be used for yield improvement wheat under combined heat-drought conditions.

1. Introduction

Wheat (*Triticum aestivum* L.) is a highly nutritious cereal that is consumed as a major staple food by 2.5 billion people in the world. (Poudel et al., 2021; Sendhil et al., 2022). It provides more than 50% calorie requirement in West and Central Asia (Sendhil et al., 2022). In Nepal, wheat serves as a staple food crop for 25% of the population providing 19% of the total calorie requirement in the diet. Wheat is the third most important cereal in Nepal in terms of production (Bhandari et al., 2021; Djanaguiraman et al., 2020). It is cultivated on 219.01 million hectares of land with the production of 760.92 million metric tons. It shares 10% value addition in agriculture, 7.14% to the agriculture's gross domestic product and covers 19% of the total cereal cultivating area of Nepal contributing (Bhatta et al., 2020).

Globally, heat stress and drought stress are the major abiotic factors for lower production of wheat (Poudel et al., 2019). Climate change induced heat and drought stress causes wheat crop routinely subjected to the simultaneous effect of both heat and drought stress. Therefore, heat stress and heat-drought conditions have been the major subject of intense research (Lamelas et al., 2023). Only 48% crop growing area of Nepal is under irrigated facilities and rest fully depend on natural rainfall for irrigation. About 25% of the total area under wheat production is under heat stress in Nepal. Furthermore, climate change is leading to a rise in temperature at the

Cite This Article

Nyaupane S, Radhakrishna Bhandari R, Poudel MR. 2024. Evaluation of Stable, and Adaptable Wheat Genotypes under Late Sown (Heat Stress) and Drought under Late Sown (Heat-Drought) Conditions. *Fundamental and Applied Agriculture*, 9(3): 162–167. https://doi.org/10.5455/faa.166603

rate of 0.06°C per year with an annual decline in precipitation of 16.09 mm (Paudel et al., 2020). Lack of irrigation reduces the annual productivity of wheat by 12000 kg ha^{-1} to 800 kg ha^{-1} (Dorostkar et al., 2015) whereas heat stress reduces the productivity up to 240 kg ha^{-1} to 1380 kg ha^{-1} (Poudel et al., 2020). Wheat suffers from heat stress when the temperature exceeds 22 °C and causes the loss up to 6% for each degree rise in temperature above it (Djanaguiraman et al., 2020). Not only the wheat yield is decreasing now but also it will decline more in future (Abhinandan et al., 2018; Lesk et al., 2016; Liu et al., 2016). Since the combined effect of this major two factors had not been studied yet, therefore, there is a prerequisite to study on the combine effect of heat stress and drought stress.

In the world about 16.67% of the total population suffers from malnutrition and 6% suffering from chronic micronutrient deficiency (MoF, 2022). Climate change and lower crop productivity would be the major subject matters for food and nutritional security of the world (Carraro et al., 2015). Increasing crop production through increasing cropping area is almost impossible since the population of the world had been increasing in drastically higher rates as compared to the area under cultivation which is only increased by 12-13% (*FAOSTAT*, 2022).. Therefore, identification of stable, adaptable genotypes of wheat is a prerequisite step for the overall improvement and food security of the world through plant breeding programs.

2. Materials and Methods

An experiment was carried out at the Agronomy farm of the Institute of Agriculture and Animal Science (IAAS), Paklihawa campus, Bhairahawa, Rupandehi from December 2021 to April 2022.

The agrometeorological parameters during the wheat growing season were obtained from the Department of Hydrology and Meteorology (DHM), Bhairahawa (Figure 1).

There were 20 elite wheat lines including 15 Nepal Lines (NL), three Bhairahawa lines (BL), and two commercial check viz; Bhrikuti and Gautam. These are the emerging lines of wheat provided by the National Wheat Research Program (NWRP), Bhairahawa (

Table **1**).

Genotypes were evaluated under late sown and drought under late sown conditions in an alpha lattice design having five blocks and four plots replicated twice with the plot dimension of 4 m × 2.5 m (10 m^2). The inter-block space was maintained at one meter, and the intra-block space was 50 centimeters. Inter-replication space was maintained at one meter. Wheat genotypes were sown on 25th December for both late sown and drought under late sown conditions. Six doses of irrigation were provided at crown root initiation (CRI), tillering, heading, flowering, milking, and soft dough stage for late sown condition while irrigation was restricted for drought under late sown condition. One-meter square area of the crop was harvested with a serrated sickle at harvestable maturity and yield data were collected for both conditions.

Microsoft Excel- 2016 was used for data entry and processing. Combined analysis of variance across genotypes and condition was performed through IBM SPSS statistics V.26. The stability and adaptability analysis of the genotypes was done through additive main effect and multiplicative interaction (AMMI) and Genotype, Genotype* Environment (GGE) biplot analysis was performed using GEAR (Version 4.0, provided by CIMMYT, Mexico). The AMMI model equation:

$Yij\mu + \alpha i + \beta j + \sum_{n=0}^{N} \lambda n \gamma in \delta jn + \theta ij + \varepsilon ij$ (Aktas, 2016a)

Where: Y*ij* = the mean yield of elite line i in environment j, μ = the grand mean of the yield, αi = the deviation of the elite lines mean from the grand mean, βj = the deviation of the environment mean from the grand mean, λn = the singular value for the PCA; n, N = the number of PCA axis retained in the model, γin = the PCA score of an elite line for PCA axis n, δjn = the environmental PCA score for PCA axis n, θij = the AMMI residual and εij = the residuals.

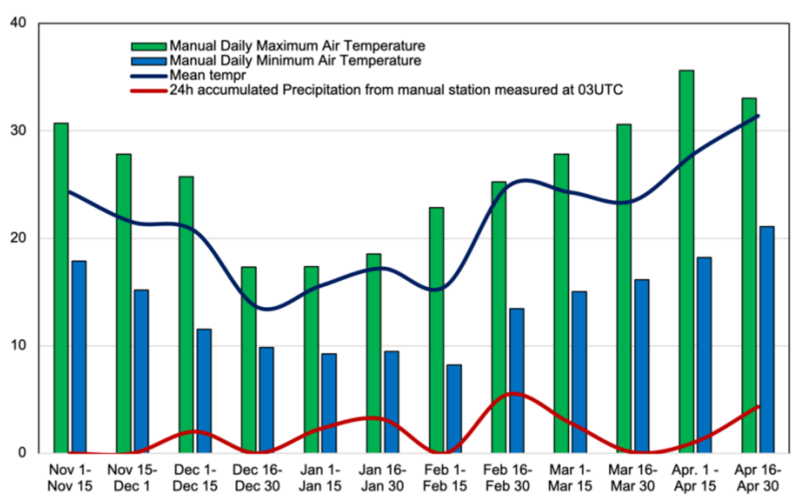

Figure 1. Agrometeorological Parameters during the wheat growing season 2021.

Table 1. Plant material used in the experiment.

Sl. No	Genotypes*	Source	Sl. No	Genotypes*	Source
1	Bhrikuti	CIMMYT, Mexico	11	NL 1376	CIMMYT, Mexico
2	BL 4407	Nepal	12	NL 1381	CIMMYT, Mexico
3	BL 4669	Nepal	13	NL1384	CIMMYT, Mexico
4	BL 4919	Nepal	14	NL 1386	CIMMYT, Mexico
5	Gautam	Nepal	15	NL 1387	CIMMYT, Mexico
6	NL 1179	CIMMYT, Mexico	16	NL 1404	CIMMYT, Mexico
7	NL 1346	CIMMYT, Mexico	17	NL 1412	CIMMYT, Mexico
8	NL1350	CIMMYT, Mexico	18	NL 1413	CIMMYT, Mexico
9	NL 1368	CIMMYT, Mexico	19	NL 1417	CIMMYT, Mexico
10	NL 1369	CIMMYT, Mexico	20	NL 1420	CIMMYT, Mexico

3. Result and Discussion

3.1. AMMI Model ANOVA

The result of AMMI model revealed that environment had a significant effect on grain yield of wheat. Environment explained 55.22% of the total variation in grain yield (**Table 2**). The first principal component (PC1) explained 100% of the total variation in grain yield (**Table 2**).

The Biplot of AMMI model consists grain yield on abscissa and principle component 1 (PC1) on ordinates. Genotypes with same yield same vertical line while the environments with similar interaction pattern lies on same horizontal line. PC scores denotes the adaptability of genotypes that is, higher the PC scores of genotypes higher would be the adaptability and vice-versa and zero PC scores or the genotypes close to origin are most stable across all tested environments (El-salam & Asran, 2018).

Table 2. AMMI Model ANOVA

	SS	PORCENT	PORCENAC	DF	MS	F	PROBF
ENV	12951083.21	55.22	55.22	1.00	12951083.21	36.11***	0.00
GEN	6808277.99	29.03	84.25	19.00	358330.42	1.00	0.48
ENV*GEN	3694826.60	15.75	100.00	19.00	194464.56	0.54	0.92
PC1	3694826.60	100.00	100.00	19.00	194464.56	0.59	0.87
Residuals	14345578.63	0	0	40	358639.47	NA	NA

Environment (ENV); Genotype (GEN); Principal Component of AMMI (PC); PORCENT= Percentage; PORCENAC= Percentage accumulated; Degree of Freedom (DF); Sum of Squares (SS); Mean sum of Squares (MS); F= F-value; PROBF= Probability of F.

NL 1404 and NL 1386 were the most stable genotypes across both late sown and drought under late sown conditions and NL 1368 and NL 1387 were the most adaptable genotypes under late sown and drought under late sown conditions, respectively (Figure 2).

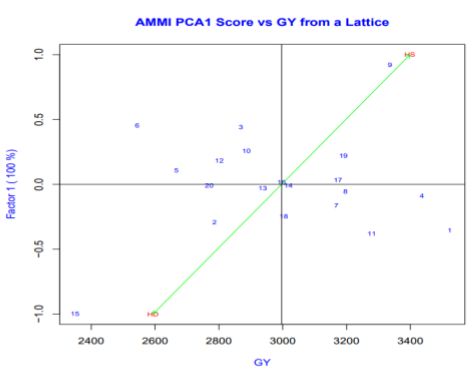

Figure 2. AMMI biplot showing PC1 vs GY of twenty wheat genotypes under late sown (HS) and drought under late sown condition (HD).

3.2. Which-Won-Where Model

It is the polygon view created by joining the vertex genotypes. The genotypes lying away from the origin and on the vertex of polygon were specifically adapted to their respective segments (Gupta & Kumar, 2019) whereas, those lying close to origin were stable across all tested conditions.

Environments fall under two sectors whereas genotypes fallunder four sectors in polygon view of WWW model (Figure 3). NL 1404 and NL 1386 were the most stable genotypes across late sown and drought under late sown conditions whereas, NL 1368 and Bhirkuti were specifically adapted genotypes under HS and HD conditions, respectively (Figure 3). The polygon view of the GGE biplot (which-win-where model) was used for the evaluation and identification of winning genotypes to a corresponding environment by Adil et al., 2022; Kendal, 2019; Neisse et al., 2018; Thungo et al., 2020).

3.3. Mean vs. Stability Model

Mean performance and stability of genotypes were the major criteria for the selection decision. GGE biplot of Mean vs. Stability model visualizes both performance and stability of genotypes using Average environment coordinates (AEC) method (Poudel, 2019). AEC passes through the origin perpendicularly and a line passing perpendicularly to the AEC was ordinates. Genotypes lies towards the direction of arrowhead were high yielding and vice-versa. Stable genotypes were located on the AEC abscissa (horizontal axis) and had a no projection on AEC (vertical axis)(Jat et al., 2017). Mean Vs stability model identifies the high-yielding and stable, high-yielding and unstable, low-yielding and stable and low-yielding genotypes across all tested environment. The best genotype has high mean yield and high stability with in mega-environment (Aktas, 2016b).

BL 4919 was the high yielding and stable genotype, Bhirkuti was the high yielding and less stable genotype, Gautam was the low yielding and stable under both conditions, and NL 1387 was the low yielding and less stable genotype across both HS and HD conditions (Figure **4**).

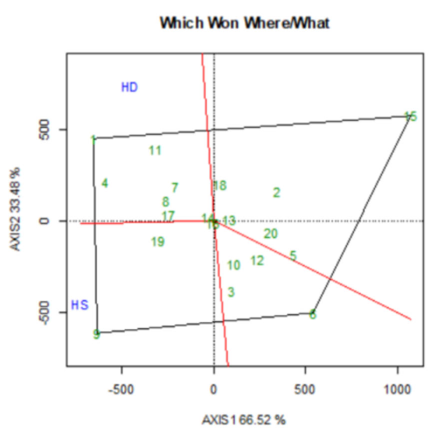

Figure 3. Which-Won-Where Model showing genotype × environment of twenty wheat genotypes under HS and HD conditions.

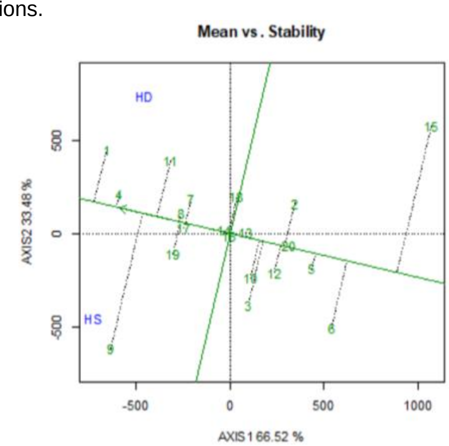

Figure 4. Mean vs. stability view of genotype showing genotype x environment interaction effect (GGY) biplot of late sown and drought under late sown condition.

3.4. Ranking Genotypes

The genotype that lies close to the arrowhead joined through a line to the origin is the ideal genotype (Khan et al., 2021). The ranking was done based on the distance of the genotypes from the arrowhead (Bishwas et al., 2021).

BL 1949 was the most ideal genotype across both conditions (Figure 5). The ranking of genotypes was in the order of; BL 4919>Bhirkuti>NL1350>NL 1412>NL 1376>NL 1417>NL 1346>NL 1386>NL 1404>NL 1413>NL 1384>NL 1368>NL 1369>BL 4669>NL 1381>BL 4407>NL 1420>Gautam>NL 1179>NL 1387.

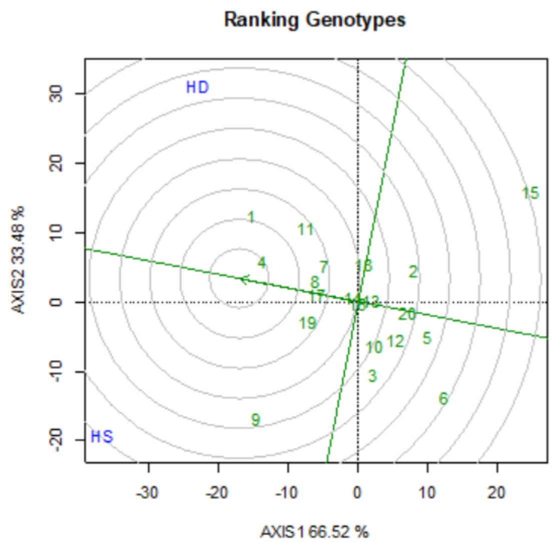

Figure 5. Ranking genotypes GGE biplot under late sown and drought under late sown conditions.

4. Conclusion

Heat stress and heat-drought conditions are the major yield limiting factor for wheat production. Identification of stable, adaptable, and heat drought tolerant genotype would help to achieve optimum yield under stressed condition. The result showed, NL 1404 and NL 1386 were the most stable genotypes across late sown and drought under late sown conditions whereas, NL 1368 and Bhirkuti were specifically adapted genotypes under HS and HD conditions, respectively and had a high yield potential under both late sown and late sown drought condition. Hence, these genotypes can be used as genetic materials for yield improvement in wheat.

Acknowledgements

We would like to acknowledge the National Wheat Research Program, Bhairahawa, for providing research materials, the Institute of Agriculture and Animal Science, Paklihawa campus Tribhuvan University, Nepal for providing research field, and the University Grant Commission (UGC), Bhaktapur, Nepal providing us the research grant (FRG-78/79- Ag&F-02) for the financial support) to experiment.

Authors' contributions

Mukti Ram Poudel and Shivalal Nyaupane conceptualized the research, performed analysis, and prepared the manuscript and publication. Radhakrishna Bhandari and Mukti Ram Poudel prepared the manuscript. The final version of the manuscript was proofread by all the authors.

Funding

University Grant Commission (UGC), Bhaktapur, Nepal provide us with a research grant (FRG-78/79- Ag&F-02) for financial support) to experiment

Conflict of interest

There was no conflict with any financial institution or funding agency that affect the results or the interpretation of the manuscript.

References

Abhinandan K, Skori L, Stanic M, Hickerson NMN, Jamshed M, Samuel MA. 2018. Abiotic stress signaling in wheat – An inclusive overview of hormonal interactions during abiotic stress responses in wheat. *Frontiers in Plant Science*, *9*(June), 1–25. https://doi.org/10.3389/fpls.2018.00734

Adil N, Wani SH, Rafiqee S, Mehrajuddin S, Sofi NR, Shikari AB, Hussain A, Mohiddin F, Jehangir IA, Khan GH. 2022. Deciphering genotype× environment interaction by ammi and gge biplot analysis among elite wheat (Triticum aestivum L.) genotypes of Himalayan region. *Ekin Journal of Crop Breeding and Genetics*, *8*(1), 41–52.

Aktas. 2016a. Tracing highly adapted stable yielding bread wheat (*Triticum Aestivum* L.) genotypes for greatly variable South-Eastern Turkey. *Applied Ecology And Environmental Research*, *14*(4), 159–176. https://doi.org/http://dx.doi.org/10.15666/aeer/1404_159176

Aktas H. 2016b. Tracing highly adapted stable yielding bread wheat (*Triticum aestivum* L.) genotypes for greatly variable South-Eastern Turkey. *Applied Ecology and Environmental Science Research, 14(4), 159-176.*

Bhandari R, Gnawali S, Nyaupane S, Kharel S, Poudel M, Panth P. 2021. Effect of drought & irrigated environmental condition on yield & yield attributing characteristic of bread wheat-a Review. *Reviews in Food and Agriculture*, *2*(2), 59–62. https://doi.org/10.26480/rfna.02.2021.59.62

Bhatta RD, Amgain LP, Subedi R, Kandel BP. 2020. Assessment of productivity and profitabilty of wheat using Nutrient Expert®-Wheat model in Jhapa district of Nepal. *Heliyon*, *6*(6), e04144. https://doi.org/10.1016/J.HELIYON.2020.E04144

Bishwas KC, Poudel MR, Regmi D. 2021. AMMI and GGE biplot analysis of yield of different elite wheat line under terminal heat stress and irrigated environments. *Heliyon*, *7*(6), e07206. https://doi.org/10.1016/j.heliyon.2021.e07206

Carraro C, Edenhofer O, Flachsland C, Kolstad C, Stavins R, Stowe R. 2015. The IPCC at a crossroads: Opportunities for reform. *Science*, *350*(6256), 34–35. https://doi.org/10.1126/science.aac4419

Djanaguiraman M, Narayanan S, Erdayani E, Prasad PVV. 2020. Effects of high temperature stress during anthesis and grain filling periods on photosynthesis, lipids and grain yield in wheat. *BMC Plant Biology*, *20*(1), 1–12. https://doi.org/10.1186/s12870-020-02479-0

Dorostkar S, Dadkhodaie A, Heidari B. 2015. Evaluation of grain yield indices in hexaploid wheat genotypes in response to drought stress. *Archives of Agronomy and Soil Science*, *61*(3), 397–413. https://doi.org/10.1080/03650340.2014.936855

El-salam RMA, Asran MR. 2018. Yield adaptability and stability of grain sorghum genotypes across different environments in egypt using ammi and gge-biplot models. *Annual Research & Review in Biology, 23(3), 1–16.* https://doi.org/10.9734/ARRB/2018/39491

FAOSTAT. 2022. http://www.fao.org/faostat/en/#data/QC

Gupta V, Kumar P. 2019. Genotype x environment interaction analysis of multi-environment wheat trials in India using AMMI and GGE biplot models. *Crop Breeding and Applied Biotechnology*, 309–318. https://doi.org/10.1590/1984-70332019v19n3a43

Jat ML, Jat RK, Singh P, Jat SL, Sidhu HS. 2017. Predicting yield and stability analysis of wheat under different crop management systems across agro-ecosystems in India. *American Journal of Plant Sciences*, *8*, 1977–2012. https://doi.org/10.4236/ajps.2017.88133

Kendal E. 2019. Comparing durum wheat cultivars by genotype × yield ×trait and genotype × trait biplot method. *Chilean Journal of Agricultural Research*, *79*(4), 512–522. https://doi.org/10.4067/S0718-58392019000400512

Khan MH, Rafii MY, Ramlee SI, Jusoh M. 2021. OPEN AMMI and GGE biplot analysis for yield performance and stability assessment of selected Bambara groundnut (*Vigna subterranea* L . Verdc.) genotypes under the multi-environmental trials (METs). *Scientific Reports*, 1–17. https://doi.org/10.1038/s41598-021-01411-2

Lamelas L, Jesús M, Valledor L. 2023. Untargeted metabolomics revealed essential biochemical rearrangements towards combined heat and drought stress acclimatization in Pinus pinaster. *Environmental and Experimental Botany*, *208*. https://doi.org/10.1016/j.envexpbot.2023.105261

Lesk C, Rowhani P, Ramankutty N. 2016. Influence of extreme weather disasters on global crop production. *Nature*, *529*(7584), 84–87. https://doi.org/10.1038/nature16467

Liu B, Asseng S, Müller C, Ewert F, Elliott J, Lobell DB, Martre P, Ruane AC, Wallach D, Jones JW, Rosenzweig C, Aggarwal PK, Alderman PD, Anothai J, Basso B, Biernath C, Cammarano D, Challinor A, Deryng D, Zhu Y. 2016. Similar estimates of temperature impacts on global wheat yield by three independent methods. *Nature Climate Change*, *6*(12), 1130–1136. https://doi.org/10.1038/nclimate3115

MoF (*Ministry of Finance*). 2022. *Economic Survey 2020/21. Government of Nepal Ministry of Finance*. Available at: https://www.mof.gov.np.

Neisse AC, Kirch JL, Hongyu K. 2018. AMMI and GGE Biplot for genotype × environment interaction: a medoid–based hierarchical cluster analysis approach for high–dimensional data . *Biometrical Letters*, *55*(2), 97–121. https://doi.org/10.2478/BILE-2018-0008

Paudel B, Zhang Y, Yan J, Rai R, Li L, Wu X, Chapagain PS, Khanal NR. 2020. Farmers' understanding of climate change in Nepal Himalayas: important determinants and implications for developing adaptation strategies. *Climatic Change*, *158*(3–4), 485–502. https://doi.org/10.1007/s10584-019-02607-2

Poudel. 2019. Assessing genetic diversity for drought and heat stress tolerance of Nepalese wheat genotypes by SSR markers Assessing genetic diversity for drought and heat stress tolerance of Nepalese wheat genotypes by SSR markers. *EurAsian Journal of Biosciences*, *13*(May 2021), 941–948.

Poudel MR, Ghimire S, Prasad P, Dhakal KH, Thapa DB, Poudel HK. 2020. Evaluation of wheat genotypes under irrigated,heat stress and drought conditions. *Journal of Biology and Today's World*, *9*(1), 212.

Poudel MR, Ghimire SK, Pandey MP, Dhakal KH, Thapa DB, Khadka DK. 2019. Assessing genetic diversity for drought and heat stress tolerance of Nepalese wheat genotypes by SSR markers. *EurAsian Journal of BioSciences Eurasia J Biosci*, *13*, 941–948. https://brcwebportal

Poudel PB, Poudel MR, Puri RR. 2021. Evaluation of heat stress tolerance in spring wheat (*Triticum aestivum* L.) genotypes using stress tolerance indices in western region of Nepal. *Journal of Agriculture and Food Research*, *5*, 100179. https://doi.org/10.1016/j.jafr.2021.100179

Sendhil R, Kumari B, Khandoker S, Jalali S, Acharya KK, Gopalareddy K, Singh GP, Joshi AK. 2022. Wheat in Asia – Trends , Challenges and Research Priorities. *New Horizons in Wheat and Barley Research. Springer, Singapore*, *January*. https://doi.org/10.2139/ssrn.4073890

Thungo Z, Shimelis H, Odindo A, Mashilo J. 2020. Genotype-by-environment effects on grain quality among heat and drought tolerant bread wheat (*Triticum aestivum* L.) genotypes. *Journal of Plant Interactions*, *15*(1), 83–92. https://doi.org/10.1080/17429145.2020.1748732