__Original Research Article__

Enhancing Wheat Nitrogen and Protein Content in Agroforestry Systems for Climate-Resilienceand Food Security

ABSTRACT

This research was conducted at the Forestry Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya in Jabalpur, Madhya Pradesh, during the consecutive Rabi seasons of 2021-22. The study employed a double split plot design with three factors: land use systems (S1- open system and S2- agroforestry system), sowing dates (D1- 12 Nov, D2- 27 Nov, D3- 12 Dec), and wheat varieties (V1 - MP-3336 and V2 - GW-322). Each experimental treatment was meticulously replicated three times to ensure robust statistical analysis. The objective of the study was to estimate nitrogen and protein content in grains of wheat under open and *Pongamia Pinnata* based agroforestry system. Nitrogen content in wheat grains was quantified using Modified Kjeldahl Method, and subsequently, protein content was calculated based on the determined nitrogen levels. The outcomes of this investigation consistently revealed that the open system consistently exhibited higher levels of nitrogen and protein content when compared to the agroforestry system. Furthermore, earlier sowing dates, particularly D1, contributed to increased nitrogen and protein content, although statistical significance was not achieved. Substantial varietal differences were observed, with MP-3336 consistently outperforming GW-322 in terms of nitrogen and protein content. These findings emphasize the critical role of land use strategies, sowing timing and wheat variety selection in augmenting the nitrogen and protein content of wheat crops, thereby making significant contributions to sustainable agricultural practices and enhancing food quality in regions reliant on wheat production.

Keywords: - Climate Change, Agroforestry, Wheat Nutrition, Food Security and Sustainable Agriculture

INTRODUCTION

In light of the profound challenges posed by climate change and global food security, the agricultural sector is at the forefront of innovation and adaptation[1]. Wheat, as one of the crucial staple crops sustaining the world's expanding population, is deeply intertwined with the intricate dynamics of changing climate patterns, sustainable land use and nutritional quality[2]. In this context, the assessment of nitrogen and protein content in wheat crops within agroforestry systems emerges as a critical research area, bridging the domains of agronomy, environmental science and nutrition[3]. This intersection underscores the imperative to address multifaceted challenges associated with climate change, ensuring the resilience and nutritional quality of wheat crops while advancing sustainable agricultural practices[4].

Climate change, marked by shifts in temperature, precipitation patterns and an increased frequency of extreme weather events, poses a significant threat to agricultural productivity [5]. Wheat, one of the world's paramount cereal crops providing a substantial source of human sustenance, exhibits heightened sensitivity to temperature and water availability, necessitating adaptation to these evolving conditions[6]. Agroforestry systems, which involve the integration of trees and crops in a single farming system, hold the potential to deliver numerous benefits, encompassing enhanced soil fertility, improved water management and augmented biodiversity[7]. These systems have been advocated as a sustainable agricultural approach capable of mitigating the impacts of climate change and enhancing food security[8,9].

Agroforestry systems that incorporate nitrogen-fixing trees have demonstrated promise in bolstering nitrogen supply and elevating wheat grain protein content when compared to conventional open field conditions [10]. Nitrogen is an essential nutrient for the growth and development of wheat, with a pivotal role in determining wheat grain protein content. The protein concentration in wheat grains is intricately linked to nitrogen content and dry mass, further segregating into various fractions [11]. The protein content of wheat is a critical determinant of its nutritional value and quality, influenced by diverse factors, including climatic conditions, cultivar selection, nitrogen management and soil fertility [12, 13]. This is of significant relevance in the context of climate change and food security, as agroforestry has the potential to enhance the nutritional quality of wheat while simultaneously offering climate change adaptation and mitigation benefits, such as carbon sequestration [14].

Climate change is impacting all four dimensions of food security-availability, access, utilization and stability. It exerts its influence on the food system by compounding existing non-climate stressors, including population growth, income expansion and heightened demand for animal-sourced products[15]. Studies have illustrated that observed climate changes have adversely affected the yields of several crops, including wheat, in lower-latitude regions, while higher-latitude regions have experienced positive impacts on crop yields, including wheat, in recent decades [16]. Furthermore, elevated atmospheric CO_2 levels are expected to markedly reduce the iron, zinc and protein content of key crops like rice, wheat, soybeans and field peas while augmenting carbohydrate levels [17].

The interplay between nitrogen and protein content in wheat is pivotal to its nutritional value. Protein is a fundamental component of human diets and wheat constitutes a primary source of plant-based protein for a substantial portion of the global population[18]. Hence, comprehending the influence of agroforestry practices on nitrogen uptake and consequently, protein content in wheat is of paramount significance for safeguarding food security, particularly in regions where wheat holds a dietary staple status[19].

2. MATERIALS AND METHODS

2.1 Experimental Location, Topography and Climate

The experiment was conducted at the Forestry Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, located in Jabalpur, Madhya Pradesh. The study was carried out within a 14-year-old agroforestry model centered around *Pongamia pinnata*. This research was conducted over a span of two years during the Rabi season of 2021-22. The research farm is situated in the Kymore Plateau and Satpura hill agro-climatic zone, which is characterized by a subtropical climate featuring hot, arid summers and cold, dry winters. The geographical coordinates of the site are approximately 23° 12' 50'' North latitude and 79° 57' 56'' East longitude. The region experiences high temperatures, with peaks reaching up to 46 °C in May and June, as well as low temperatures, which drop to 2 °C in December and January. The average annual rainfall in this area is approximately 1350 mm, with the majority of precipitation occurring between June and September. The predominant soil type in the region is characterized by black color, and the topography exhibits gentle slopes with a gradient ranging from 0 to 1 percent. The selection of this location serves to provide a representative illustration of the prevailing agro-climatic conditions in the region, thus offering valuable insights into the interrelationships and performance of *Pongamia pinnata* and various wheat varieties within the specified agroforestry model.

2.2 Experimental Details

The experiment was structured as a three-factor double split-plot design. The primary plot was comprised of two distinct systems: S1, characterized as an open system, and S2, denoting an agroforestry system. Within the subplot factor, there were three distinct sowing dates: D1 on the 12th of November, D2 on the 27th of November, and D3 on the 12th of December. Within each subplot, the sub-subplot factor encompassed two distinct wheat varieties: V1, specifically MP-3336 and V2, represented by GW-322. Each of these treatment combinations was replicated three times to ensure statistical rigor. The data collected from the experiment underwent rigorous statistical analysis of variance, following the recommended methodology outlined by [20].

2.3 Estimation of Nitrogen and Protein content

In this investigation, the quantification of nitrogen content in wheat grain was carried out utilizing the Modified Kjeldahl Method, a well-established and widely recognized technique for nitrogen analysis. The procedure commenced with the mixing of 0.5 grams of finely powdered grain with 10 ml of a diacid solution, composed of a 9:1 ratio of H_2SO_4 (sulfuric acid) to $HClO_4$ (perchloric acid). This mixture was allowed to stand overnight. Subsequently, a total of 10 grams of a sulfate mixture, consisting of 20 parts K_2SO_4 (potassium sulfate), along with 1 part of a catalyst mixture containing 20 parts $CuSO_4$ (copper sulfate) and 1 part of selenium powder, was introduced into the digestion tube. The mixture was then subjected to heating until a clear and colorless solution was achieved. Following the cooling of the solution, it was subjected to filtration through Whatman No. 42 filter paper, and the filtrate was collected in a 50 ml volumetric flask. Distilled water was added to bring the volume up to the mark on the flask. The distillation process involved the placement of 10 ml of a 4% boric acid solution, containing bromocresol green and methyl red indicators, in a conical flask. Subsequently, 5 ml of the filtered solution was transferred to the distillation flask of a micro-Kjeldahl apparatus, followed by the addition of 10 ml of a 40% NaOH (sodium hydroxide) solution. Once distillation was complete, titration was performed using a 0.02 N H_2SO_4 (sulfuric acid) solution. The nitrogen content in the samples was then determined using the following formula:

$$Nitogen content = \frac{0.02 \times T \times 0.014 \times 50 \times 50}{5 \times 0.5}$$

(Where, T = Sample reading - Blank reading)

The protein content in the sample was estimated using the nitrogen content previously determined by the Modified Kjeldahl Method. The conversion factor used for this estimation was 5.75.

Protein (%) = Nitrogen % x 5.75

3. RESULT AND DISCUSSION

3.1 Nitrogen content in grain of wheat varieties as influenced by wheat varieties, sowing dates and different land use systems

The recorded observations pertaining to the impact of diverse land use systems, varying sowing dates, and distinct wheat varieties on nitrogen content within the agri-silviculture context centered around *Pongamia pinnata* have been documented in Table 1 and visually depicted in Figure 1. These graphical and tabular presentations distinctly highlight a discernible pattern, indicating that the nitrogen content in wheat is notably influenced by the intricate interplay of different land use systems sowing dates and wheat varieties. This pronounced correlation remains consistently significant across both experimental years and is further affirmed through the mean analysis conducted. The experiment measured the nitrogen content (in percentage) of wheat crops in two different systems: open systemand agroforestry system over two consecutive years. In the first year, the nitrogen content in the open system was 1.73%, while in the agroforestry system it was slightly lower at 1.69%. In the second year, the nitrogen content in open system increased to 1.76%, and in agroforestry system, it increased to 1.70%. The mean nitrogen content over both years was 1.74% for open system and 1.70% for agroforestry system. The results show that the nitrogen content of wheat crops was slightly higher in the open system compared to the agroforestry system across both the experimental years. This could be attributed to increased nutrient availability and reduced competition for resources in open system, thereby enhancing nitrogen assimilation [21]. The differences between the two systems were statistically significant, with the open system having higher nitrogen content in both the first and second years. The nitrogen content of wheat crops for three different sowing dates: D1 - Nov. 12, D2 - Nov. 27, and D3 - Dec. 12, over two consecutive years were estimated. In the first year, Nov. 12 had a nitrogen content of 1.73%, Nov. 27 had 1.71%, and Dec. 12 had 1.70%. In the second year, Nov. 12 had a nitrogen content of 1.74%, Nov. 27 had 1.73%, and Dec. 12 had 1.72%. The mean nitrogen content over both years was 1.74% for Nov. 12, 1.72% for Nov. 27, and 1.71% for Dec. 12. The results indicate that, earlier sowing date (Nov. 12) consistently resulted in higher nitrogen content compared to Nov. 27 and Dec. 12, possibly due to extended growth period allowing for increased nutrient uptake [22, 23], however the differences were statistically non-significant. Additionally, the experiment aimed to measure the nitrogen content of wheat crops for two different varieties: MP-3336 and GW-322, over two consecutive years. In the first year, MP-3336 had a nitrogen content of 1.73%, while GW-322 had 1.69%. In the second year, MP-3336 had a nitrogen content of 1.75%, and GW-322 had 1.71%. The mean nitrogen content over both years was 1.74% for MP-3336 and 1.70% for GW-322. The results indicate that there were slight differences in nitrogen content between the two wheat varieties. In the first year, MP-3336 had a slightly higher nitrogen content compared to GW-322. The trend continued in the second year, with MP-3336 still showing slightly higher nitrogen content than GW-322 with statistically significant differences. Wheat variety MP-3336 consistently exhibited higher nitrogen content compared to GW-322, possibly reflecting varietal differences in nutrient uptake efficiency. The study by [24] emphasized varietal impact on nutrient content.

3.2 Protein content in grain of wheat varieties as influenced by wheat varieties, sowing dates and different land use systems

The observation regarding the effect of different land use system, sowing dates and varieties on protein content under *Pongamia pinnata* based agri-silviculture system are presented in table 1 and depicted in figure 1. It is evident that wheat protein content was significantly affected by different land use system, date of sowing and wheat varieties in both the years of experimentation as well as in mean analysis.

In the first year, the protein content in the open system was 9.95%, and in the agroforestry system, it was 9.73%. In the second year, the protein content in open system increased to 10.11%, while in agroforestry system, it increased to 9.80%. The mean protein content over both years was 10.03% for open system and 9.76% for agroforestry system. The results indicate that there were slight differences in protein content between the two systems. The open system had slightly higher protein content than the agroforestry system in both the first and second years with differences being statistically significant. This could be attributed to the open system's favorable conditions for protein synthesis, aided by ample sunlight exposure and reduced competition for resources [25].The protein content of wheat crop for three different sowing dates: Nov. 12, Nov. 27, and Dec. 12, over two consecutive years were determined. In the first year, Nov. 12 had a protein content of 9.94%, Nov. 27 had 9.82%, and Dec. 12 had 9.77%. In the second year, Nov. 12 had a protein content of 10.02%,Nov. 27 had 9.96%, and Dec. 12 had 9.87%. The mean protein content over both years was 9.98% for Nov. 12, 9.89% for Nov. 27, and 9.82% for Dec. 12. Overall Nov. 12 showed higher protein content than Nov. 27 and Dec. 12 in both years as well as in mean analysis. The earlier sowing date (Nov. 12) also consistently resulted in higher protein content despite, the differences were statistically non-significant, it is likely due to the extended grain-filling duration allowing for greater protein accumulation [26]. Moreover, the protein content of wheat crop for two different varieties: MP-3336 and GW-322, over two consecutive years was also measured. In the first year,MP-3336 had a protein content of 9.96%, while GW-322 had 9.72%. In the second year, MP-3336 had a protein content of 10.05%, and GW-322 had 9.85%. The mean protein content over both years was 10.01% for MP-3336 and 9.79% for GW-322. The results indicate that there were slight differences in protein content between the two varieties. Varietal differences were again evident, with MP-3336 consistently exhibiting higher protein content compared to GW-322 with statistically significant differences. This could be attributed to inherent genetic traits influencing protein synthesis in the respective varieties [27].

Table 1: Nitrogen and Protein content in grain of wheat varieties as influenced by wheat varieties, sowing dates and different land use systems

Treatments	Nitrogen %			Protein %		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean
Systems						
S_1- Open	1.73	1.76	1.74	9.95	10.11	10.03
S_2- Agroforestry	1.69	1.70	1.70	9.73	9.80	9.76
SEm±	0.01	0.01	0.01	0.05	0.04	0.03
CD (P = 0.05)	0.05	0.04	0.04	0.30	0.25	0.17
Date of sowing						
D_1- Nov. 12	1.73	1.74	1.74	9.94	10.02	9.98
D_2- Nov. 27	1.71	1.73	1.72	9.82	9.96	9.89
D_3- Dec. 12	1.70	1.72	1.71	9.77	9.87	9.82
SEm±	0.01	0.01	0.01	0.06	0.07	0.06
CD (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Varieties						
V_1- MP-3336	1.73	1.75	1.74	9.96	10.05	10.01
V_2- GW-322	1.69	1.71	1.70	9.72	9.85	9.79
SEm±	0.01	0.01	0.01	0.05	0.04	0.02
CD (P = 0.05)	0.03	0.02	0.03	0.14	0.12	0.07

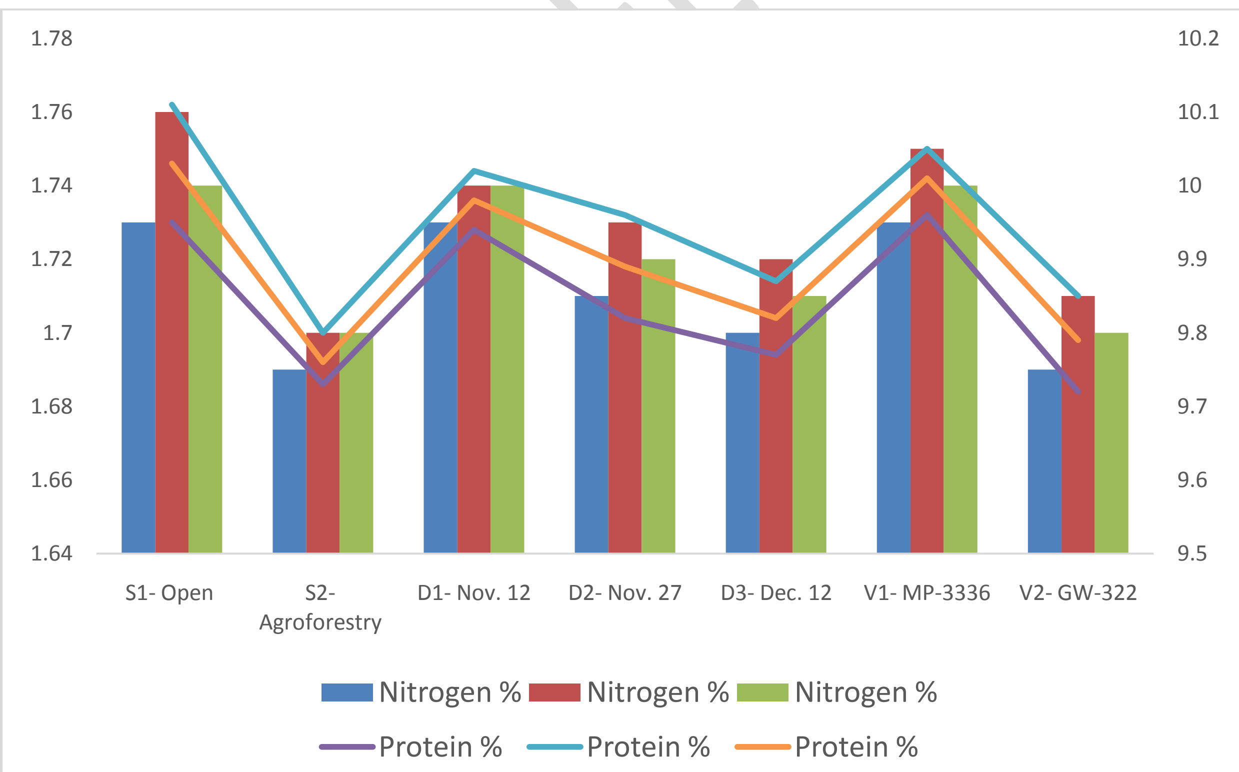

Figure 1:Nitrogen and Protein content in grain of wheat varieties as influenced by wheat varieties, sowing dates and different land use systems

CONCLUSION

In Conclusion, this research underscores the vital significance of addressing the pressing challenges presented by climate change and global food security within the agricultural domain. Wheat, a cornerstone of sustenance for the burgeoning global population, is intricately intertwined with the intricacies of shifting climate patterns, sustainable land management and nutritional attributes. The examination of nitrogen and protein levels in wheat crops within agroforestry systems plays a pivotal role in bridging the different domains ofscience likeagronomy, environmental science and nutrition etc. The results highlight a consistent trend where open agricultural systems consistently manifest elevated nitrogen and protein content in comparison to agroforestry systems, underscoring the significance of nutrient availability and reduced resource competition. Additionally, early sowing dates contribute to heightened nutrient content, while variations in wheat cultivars exhibit discernible disparities. These findings advocate for the implementation of sustainable agricultural methodologies that enhance both food security and nutritional quality, particularly in regions where wheat serves as a dietary staple. Such measures are essential in building resilient and nourishing agricultural systems in the context of climate change.

FUTURE SCOPE

The future research prospects stemming from this study encompass comprehensive investigations into the underlying mechanisms that govern nitrogen and protein content in wheat within agroforestry systems. Subsequent inquiries may delve into the genetic and physiological determinants contributing to varietal disparities, facilitating the development of wheat cultivars fine-tuned for nutritional optimization. Conducting extensive, extended assessments of the sustainability and adaptability of agroforestry in diverse agro-climatic contexts holds substantial significance. Upscaling these discoveries to broader geographical regions can furnish holistic insights for effectively addressing the intricate challenges posed by climate change and food security through the integration of agricultural and forestry methodologies. This study serves as a foundational stride towards the establishment of sustainable and nutritive agricultural systems for the forthcoming agricultural landscape.

REFERENCES

1. Lioubimtseva E, Henebry GM. Climate and environmental change in arid Central Asia: Impacts, vulnerability, and adaptations. Journal of Arid Environments. 2009; 73(11): 963-977.
2. Finley JW, Dimick D, Marshall E, Nelson GC, Mein JR, Gustafson DI. Nutritional sustainability: Aligning priorities in nutrition and public health with agricultural production. Advances in nutrition, 2017;8(5): 780-788.
3. Altieri MA. Agroecology: the science of natural resource management for poor farmers in marginal environments. Agriculture, ecosystems and environment, 2002; 93(1-3): 1-24.
4. Chandio AA, Ozdemir D, Jiang Y. Modelling the impact of climate change and advanced agricultural technologies on grain output: Recent evidence from China. Ecological Modelling. 2023; 485: 110501.
5. Abbass K, Qasim MZ, Song H, Murshed M, Mahmood H, Younis I. A review of the global climate change impacts, adaptation, and sustainable mitigation measures. Environmental Science and Pollution Research, 2022; 29(28): 42539-42559.
6. Albahri G, Alyamani AA, Badran A, Hijazi A, Nasser M, Maresca M, Baydoun E. Enhancing Essential Grains Yield for Sustainable Food Security and Bio-Safe Agriculture through Latest Innovative Approaches. Agronomy. 2023;13(7): 1709.
7. Dagar JC, Tewari VP. Evolution of agroforestry as a modern science. Agroforestry: Anecdotal to modern science 2017:13-90.
8. Kubar MS, Zhang Q, Feng M, Wang C, Yang W, Kubar KA, Riaz S, Gul H, Samoon HA, Sun H, et al. Growth, Yield and Photosynthetic Performance of Winter Wheat as Affected by Co-Application of Nitrogen Fertilizer and Organic Manures. Life. 2022;12(7):1000.

9. Khangura R, Ferris D, Wagg C, Bowyer J. Regenerative Agriculture-A Literature Review on the Practices and Mechanisms Used to Improve Soil Health. Sustainability. 2023;15(3):2338.
10. Xia H, Zhao J, Sun J, Bao X, Christie P, Zhang F, Li L. Crop acquisition of phosphorus, iron and zinc from soil in cereal/legume intercropping systems: a critical review. Annals of Botany, 2013;112(2):377-393.
11. Li X, Zhou L, Liu F, Zhou Q, Cai J, Wang X, Dai T, Cao W, Jiang D. Variations in Protein Concentration and Nitrogen Sources in Different Positions of Grain in Wheat. Frontier in Plant Science. 2016; 7:942.
12. Ghimire D, Das S, Mueller ND, Creech CF, Santra D, Baenziger PS, Easterly AC, Maust B, Maharjan B. Effects of cultivars and nitrogen management on wheat grain yield and protein. Agronomy Journal. 2021; 113(5): 4348-4368.
13. Lollato R, Figueiredo BM, Dhillon JS, Arnall DB, Raun WB. Wheat grain yield and grain-nitrogen relationships as affected by N, P, and K fertilization: A synthesis of long-term experiments. Field Crops Research. 2019; 236:42-57.
14. Jose S, Gillespie AR, Pallardy SG. Interspecific interactions in temperate agroforestry. Agroforestry Systems. 2004;61: 237-255.
15. Kubik Z, Mirzabaev A, May J. Climate Change, Food and Nutrition Security, and Human Capital. In Handbook of Labor, Human Resources and Population Economics Cham: Springer International Publishing. 2023: Pp. 1-37.
16. IPCC. Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. 2019; Pp. 131.
17. Gunaratne MS, Firdaus RRB, Rathnasooriya SI. Climate change and food security in Sri Lanka: towards food sovereignty. Humanities and Social Sciences Communications. 2021; 8: 229.
18. Kumar M, Tomar M, Punia S, Dhakane-Lad J, Dhumal S, Changan S, Kennedy JF. Plant-based proteins and their multifaceted industrial applications. Lwt. 2022; 154: 112620
19. Farooq MS, Uzair M, Raza A, Habib, M, Xu Y, Yousuf M, Khan RM. Uncovering the research gaps to alleviate the negative impacts of climate change on food security: a review. Frontiers in plant science. 2022;13: 927535.

20. Gomez KA, Gomez AA. Statistical procedures for agricultural research (2 ed.). John wiley and sons, New York, 1984; Pp.680.
21. Jia J, Xu M, Bei S, Zhang H, Xiao L, Gao Y, Zhang Y, Sai L, Xue L, Lei J, Qiao X. Impact of reduced light intensity on wheat yield and quality: Implications for agroforestry systems. Agroforest System. 2021; 95:1689-1701.
22. Gill RIS, Singh B, Kaur N. Productivity and nutrient uptake of newly released wheat varieties at different sowing times under poplar plantation in north-western India. Agroforestry Systems. 2009; 76: 579-590.
23. Jat RK, Singh P, Jat ML, Dia M, Sidhu HS, Jat SL, Bijarniya D, Jat HS, Parihar CM, Kumar U, Ridaura SL. Heat stress and yield stability of wheat genotypes under different sowing dates across agro-ecosystems in India. Field Crops Research. 2018;218: 33-50.
24. Punia S, Sandhu KS, Siroha AK. Difference in protein content of wheat (*Triticum aestivum L.*): effect on functional, pasting, color and antioxidant properties. Journal of the Saudi Society of Agricultural Sciences 2017;2(3):21-28.
25. Qiao X, Sai L, Chen X, Xue L, Lei J. Impact of fruit-tree shade intensity on the growth, yield, and quality of intercropped wheat. Plos One. 2019;14(4): e0203238.
26. Yusuf M, Kumar S, Dhaka AK, Singh B, Bhukar A. Performance of wheat (*Triticum aestivumL.*) varieties to different sowing dates. Agricultural Science Digest. 2019;39(4): 308-310.
27. Alam MS, Kumar R, Patel JN. Effect of sowing dates and varieties on the nutrient uptake and economics of Wheat crop (*Triticum aestivum L.*) under changing climate. The Pharma Innovation Journal. 2022;11(2):533-538.