Assessment and Analysis of Agricultural Technology Adoption in Biofortified Zinc Wheat Cultivation in Punjab

Introduction:

In Punjab, the adoption of biofortified zinc wheat cultivation represents a pivotal step towards addressing malnutrition and enhancing agricultural productivity. This assessment aims to comprehensively analyze the adoption patterns and impacts of this innovative technology.

The study was conducted in 3 districts of Punjab, namely Bahawalpur, Multan, and Khanewal, where AGAHE is implementing a Biofortified Zinc Wheat project with the technical support of GAIN, titled "Scaling up of Biofortified Zinc Wheat." This makes it essential to document according to subject. A total of 450 farmers (including 90 females) were randomly selected to participate in the study from 3 districts, and data were gathered through a survey method.

AGAHE seeks to understand the factors influencing farmers' decisions to adopt biofortified zinc wheat. Factors such as access to seeds, knowledge dissemination, socio-economic status, and institutional support will be meticulously examined.

Furthermore, the analysis will delve into the agronomic practices associated with biofortified zinc wheat cultivation, including seeding rates, fertilizer application, etc. By identifying best practices and challenges, we aim to optimize agricultural productivity while ensuring environmental sustainability.

Ultimately, this assessment seeks to inform policy interventions and development strategies aimed at scaling up biofortified zinc wheat cultivation in Punjab. By harnessing the potential of agricultural technology, we aspire to improve food security, nutrition outcomes, and livelihoods for rural communities in the region.

Methodology

Data

The study's data collection method involved interviews using semi-structured questionnaires administered randomly to 450 Bio Fortified Zinc Wheat Growers across three districts in April 2024. The respondents, typically the farm household member responsible for farm management decisions and registered with the project, provided demographic information, crop production details, and soil management practices, including adaptation trends. Data encompassed variables such as age, gender, educational qualifications, farm size, farm type, and area under Biofortified Zinc Wheat (BZW), alongside specifics on BZW varieties sown, seed rates, fertilizer (both

chemical and organic) application, pesticide usage patterns, weed management practices, and other relevant factors.

Table 1: The below table is showing the different technologies used for examination in this study.

Description		
Natural Resource Management	Technologies that have been "developed to deal with and mitigate environmental stresses	Minimum/zero tillage Intercropping Crop rotation Agro Forestry Own seed Timely sowing Seed Quantity
Improved varieties	Biofortified Zinc verities	BZW verities
Chemical Inputs	Agrochemical inputs intended to increase yields or reduce losses to pests	Pesticides Organic fertilizer Seed treatment before sowing
Mechanization and Infrastructure	Any of a variety of technologies requiring significant investment in physical equipment	Petrol/diesel groundwater pump Planter Drill Sowing Laser Land Leveler Deep Plough Storage process (Hermetic bags, moisture meters etc) Staking of different verities

Our analysis relied on primary survey data collected by third-party data collectors in April 2024 from registered farmers across the three districts. A pre-tested semi-structured data collection tool was utilized, developed after a thorough review of related literature. The data collector team, consisting of two enumerators, underwent orientation training before executing the data collection process. Following a dummy data collection exercise and subsequent revisions, actual data entry was conducted using SPSS-21, with minor tool adjustments made as necessary.

One-on-one interviews were then conducted with randomly selected farmers, and the collected data was entered into SPSS-21 for analysis. Enumerators were hired to ensure data accuracy, confidentiality, and to minimize bias, given the pre-existing familiarity of farmers with the AGAHE team. This decision was made in consultation with the project manager from GAIN to uphold impartiality.

Research Methodology

Our study delves into diverse facets of enhanced technologies and practices, encompassing the determinants influencing their adoption, the factors facilitating their dissemination, and the efficacy of interventions aimed at their promotion.

Study area:

The study was conducted in 3 districts of Punjab, namely Bahawalpur, Multan, and Khanewal. AGAHE is spearheading the implementation of a Biofortified Zinc Wheat project in collaboration with GAIN across these districts.

Sampling:

The was utilized for the finalization of the samples from each district.

We estimated means within each stratum (male and female) in each district to calculate the sample size:

$n=Z2\times p\times(1-p)E2n=E2Z2\times p\times(1-p)$

Where:

- nn = required sample size
- ZZ = Z-score corresponding to the desired confidence level (e.g., for a 95% confidence level, ZZ is approximately 1.96)
- pp = estimated proportion of individuals in the population (you may use 0.5 as a conservative estimate if no prior information is available)
- EE = margin of error (desired level of precision, typically expressed as a proportion

The total population of the farmers in the 3 districts is as under:-

Table 2: Total population

	Khanewal	**Bahawalpur**	**Multan**
Total Farmers	4839	4810	4331
Male	4421	4396	4133
Female	418	414	198

Thus the sample size will be:-

1. For Khanewal District: 150
- Sample Size for Male Farmers: 137
- Sample Size for Female Farmers: 13

2. For Bahawalpur District: 150

- Sample Size for Male Farmers: 138
- Sample Size for Female Farmers: 12

For Multan District: 150
- Sample Size for Male Farmers: 143
- Sample Size for Female Farmers: 7

Ethical Consideration:

Farmers were briefed on their voluntary participation rights, including the freedom to withdraw consent at any stage. After obtaining verbal consent, their data was collected confidentially, ensuring anonymity and ethical integrity.

RESULTS AND DISCUSSION

A total of 350 BZW growers (32 female) were selected through stratified random sampling technique form different villages in Multan (M: 143 & F:7), Khanewal (M:137 & F:13) and Bahawalpur (M:138 & F:12) in South Punjab (table 3).

The demographic analysis of BZW (Biofortified Zinc Wheat) farmers in the study area reveals several different trends. The mean age of male farmers stands at 2.6 years, with a standard deviation of 1.19, while female farmers have a slightly higher mean age of 2.84 years and a standard deviation of 1.08. Most farmers fall within the age range of 30-39, indicating a relatively young workforce engaged in BZW cultivation. Family size analysis demonstrates that the majority of households comprise 5 to 8 members, with male respondents' households having a higher of 56.9% compared to female respondents' households at 43.8%. Nuclear families dominate the landscape, although joint families also exhibit significant representation, particularly among female respondents' households.

Education levels among farmers reveal that the majority have qualifications below SSC, with of 32 % for male and 28% for female respondents. However, SSC and HSSC education levels also have substantial representation, suggesting a diverse educational background among BZW farmers. Farm size analysis indicates that the majority of farms are small, with less than 5 acres under cultivation, demonstrating 67.5 % for male and 87.5 % for female participants of the study. Additionally, most farms are owned by the farmers themselves, 99% for male respondents and 87.5% for female-headed households, underscoring the importance of land ownership in agricultural practices.

Table 3: Demographic background of BZW farmers and farms in Study area

Characteristics of farmers	Frequency		Percentage (%)		Mean		Standard deviation (SD)	
	Male	Female	Male	Female	Male	Female	Male	Female
Age of the farmer (years)					2.6	2.84	1.19	1.08
18-29	74	4	18	13				
30-39	124	8	30	25				
40-49	109	10	26	31				
50-59	77	9	18	28				
60 or above	37	1	8	3				
Minimum & Maximum	19 & 80	24 & 60						
Family size								
1 to 4	107	7	25.6	21.9				
5 to 8	238	14	56.9	43.8				
9 or above	73	11	17.5	34.4				
Family structure								
Nuclear	129	14	30.9	43.7				
Joint	280	18	67	56.3				
Extended	9	0	2.1	0				
Educational qualification								
Illiterate	32	11	8	34				
below SSC	133	9	32	28				
SSC	163	10	39	31				
HSSC	57	1	14	3				
Graduation or above	33	1	8	3				
Farm size under BZW								

Less than 5 acres: Small	282	28	67.5	87.5				
5 to 10 acres: Medium	97	4	23.2	12.5				
More than 10 acres: Large	39		9.3					
Type of farm								
Own	414	28	99	87.5				
Tenant	4	4	1	12.5				

Cultivated BZW verities in 2023:

The table 4 illustrates that the majority of respondents, accounting for 93.43%, have cultivated the "Akbar" variety, indicating a significant prevalence of this variety within the sample. In contrast, the "Nawab" variety represents a smaller proportion, constituting only 6.29% of the respondents. Additionally, the "Zincol" variety, which was cultivated between 2023-2024, is the least represented, with only 0.29% of respondents.

Table 4: Cultivated Verity in 2023-2024

Verity	Frequency	Percent
Akbar	327	93.42857
Nawab	22	6.285714
Zincol	1	0.285714

Awareness Regarding BZW before project intervention:

The analysis indicates that the vast majority, 98.7%, of respondents were not aware of biofortified zinc wheat before this project. While only a very small percentage, 1.3%, reported being aware of it prior to the project. This suggests a significant lack of awareness regarding biofortified zinc wheat among the respondents, highlighting the importance of projects aimed at raising awareness and promoting the adoption of such agricultural innovations.

Table 5: Were you aware of biofortified zinc wheat before this project?

Response	Frequency	Percent
No	444	98.7
Yes	6	1.3

The table 6 indicates that negligible percentage of respondents, 0.9%, heard about biofortified zinc wheat from digital media sources such as Facebook or the internet, while an even smaller proportion, 0.4%, learned about it from print media such as newspapers or magazines. The vast majority of respondents, 98.7%, did not know before project intervention.

Table 6: If yes, where from you heard about BZW.

Response	Frequency	Percent
From Media (Facebook, internet	4	0.9
From Print Media (Newspaper, magazine)'	2	0.4
NA	444	98.7

Training on BZW:

All the respondents shared that they have participated in training under the project and were growing the BZW.

Impact of training:

The table 7 indicates that respondents' knowledge levels regarding the nutritional benefits of biofortified zinc wheat vary. A low portion, 2.9%, reported having limited knowledge about these benefits, while 28.9% described their knowledge as moderate. A smaller percentage, 23.3%, claimed to possess advanced knowledge, and 42.0% characterized their understanding as comprehensive. Similarly, another 2.9% admitted to having zero knowledge about the nutritional benefits of biofortified zinc wheat. This distribution suggests a range of awareness levels among respondents.

Table 7: How would you describe your knowledge level regarding the nutritional benefits of biofortified zinc wheat?'

Response	Frequency	Percent

Advance Knowledge	105	23.3
Limited Knowledge	13	2.9
Comprehensive Knowledge	189	42.0
Moderate Knowledge	130	28.9
Zero Knowledge	13	2.9

Adoption of Better Management practices by BZW growers:

The analysis of agricultural technology adoption among respondents presents a comprehensive overview of the prevailing trends in the implementation of various practices (table 8). Notably, practices such as timely sowing, proper labeling of zinc wheat and crop rotation exhibit a remarkable 100% adoption rate, underscoring their indispensable role in optimizing crop yields and maintaining soil health. This high level of adoption reflects the recognition among respondents of the pivotal importance of these practices in sustainable agricultural management.

Moreover, a significant proportion of respondents (89%) express a preference for self-sourced seeds over external suppliers, indicative of a prevailing ethos of self-reliance and the preservation of traditional agricultural methods. Similarly, practices like the appropriate use of pesticides (93%) and seed treatment before sowing (70%) garner relatively high adoption rates, highlighting their perceived efficacy in pest control and crop protection (table 8).

However, certain technologies face notable challenges in adoption, as evidenced by their lower uptake among respondents. For instance, practices such as drill sowing (41%), and laser land leveling (44) are embraced by less than half of the respondents. This suggests the presence of barriers to adoption, which may include factors like limited access to equipment, insufficient awareness of benefits, or financial constraints.

Furthermore, practices such as the use of organic fertilizers, composting, and agroforestry demonstrate minimal to no adoption, indicating a potential lack of awareness or perceived benefits among respondents regarding these techniques. These findings underscore the need for targeted interventions and educational programs to address barriers to adoption and promote the uptake of sustainable agricultural practices for enhanced productivity and environmental stewardship.

Table 8: **Have you adopted any of the following agricultural technologies/ techniques on your farm?**

Response	Frequency	Percent
Drill sowing	184	41
Laser land Level	198	44
Own Seed	400	89
Timely Sowing	450	100
Crop Rotation	450	100
use oh Hermetic Bags	8	2
Use of recommended seed quantity	450	100
appropriate use of pesticides	418	93
proper labeling of zinc wheat	450	100
soil testing	114	25
Use of fertilizer after soil analyses	114	25
Deep plough after 3 years	75	17
Seed treatment before sowing	317	70
Minimum/zero tillage	0	0
Agroforestry	0	0
Use of organic fertilizers	0	0
Use of compost	4	1
storage processes (staking of different varieties)	450	100

Why adaptation of BMPs:

Table 9 indicates the factors influencing the decision to adopt agricultural technologies reveals that all respondents adopted due to "More Yield" and "Nutritional Benefit" as influential factors, with 100% adaptation rate. This indicates a strong emphasis placed by farmers on increasing crop yield and enhancing the nutritional quality of their produce as primary motivators for technology adoption. Additionally, "Nutritional Yield" was reported by 88.4% of respondents, further emphasizing the importance of nutritional considerations in agricultural decision-making.

Furthermore, "Economic Factor" emerged as another significant influencer, with 85.6% of respondents indicating its importance. This suggests that economic considerations, such as cost-effectiveness, return on investment, and overall profitability, play a crucial role alongside yield and nutritional benefits in driving technology adoption decisions.

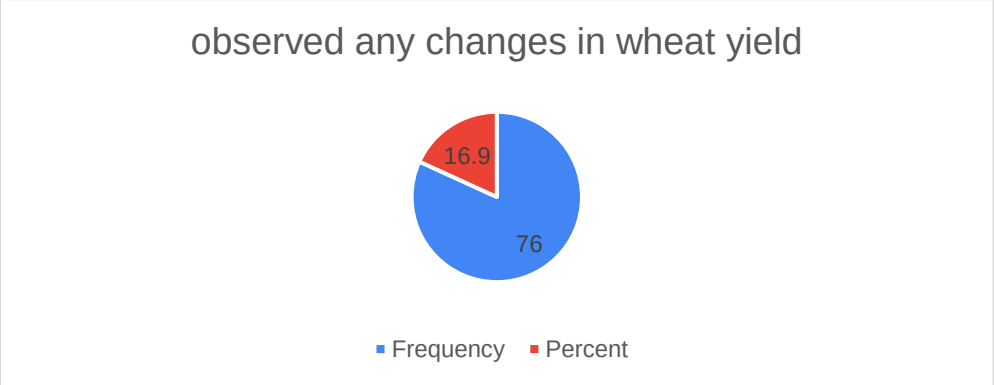
Table 9: What factors influenced your decision to adopt the mentioned above agricultural technologies?

Response	Frequency	Percent
More Yield	450	100.0
Nutritional benefit	450	100.0
Nutritional Yield	398	88.4
Economic Factor	385	85.6

Impact of Adoption on wheat yield:

Figure 1 reveals that 83.1% of respondents observed positive changes in wheat yield following the adoption of agricultural technologies, indicating their perceived effectiveness. Conversely, 16.9% reported no observed changes. This suggests a significant impact of technology adoption on wheat yield, although a minority did not perceive such changes.

Fig 1: Have you observed any changes in wheat yield since adopting these technologies?



If yes which changes you observed"

Among respondents who observed changes in wheat yield, 83.1% reported a better yield compared to previous years, highlighting the positive impact of technology adoption (table 10).

Table 10: If yes, please describe the difference in yield.

Response	Frequency	Percent
better yield	374	83.1
NA	76	16.9

Reasons for not adopting new technologies

Table 11 highlights that economic factors were cited as the primary reason for not adopting new technologies/BMPs by 55.6% of respondents. Additionally, 32.4% expressed fear of adopting new technologies, while 12.0% reported a lack of trust in these innovations.

Table 11: Reasons for not adopting the new technologies/BMPS:

Response	Frequency	Percent
Economic Factors	250	55.6
Fear of adopting new technologies	146	32.4
Not trust in new technologies	54	12.0

Reasons for use of own seed:

The decision to use their own seeds was primarily influenced by economic factors, as reported by 44.4% of respondents. Additionally, 28.9% cited the perceived higher quality of their own seeds, while 15.6% expressed a lack of trust in others' seeds (table 12).

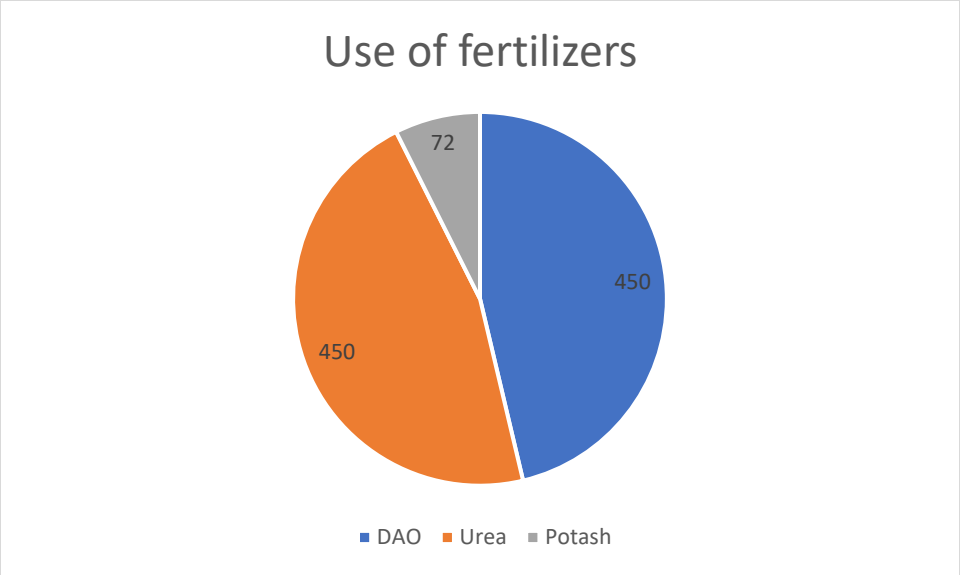
Table 12: what factors influenced your decision to use your own seeds?

Response	Frequency	Percent
Economical	200	44.4
Not trust in others seeds	70	15.6
Own seed quality is good	130	28.9
NA	50	11.1

Use of fertilizers:

All farmers in the study reported using DAP (Diammonium phosphate) and Urea fertilizers, indicating their widespread adoption for agricultural purposes. However, only a minority, comprising 16% of the respondents, reported using Potash fertilize (fig 2).

Fig 2: Use of fertilizers



Use of Pesticides:

All the farmers used different weedicides and herbicides.

Use of technology App:

All the farmers were unaware regarding the App (table 13).

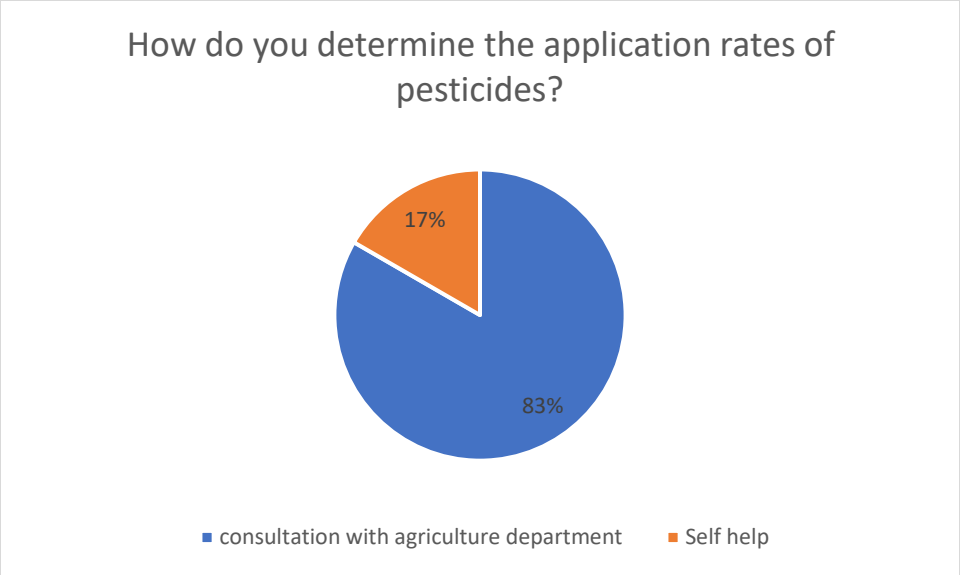
Table 13: Do you use any app like PWD app, Bakhabar kissan to get prediction of weather forecast for controlling your own farm irrigation practices?

Response	Frequency	Percent
I don't know	450	100.0

Selection of Pesticide:

The fig 3 explicit the responses regarding the determination of pesticide application rates reveals that the majority of farmers, accounting for 83.3%, rely on consultations with the agriculture department to determine the appropriate application rates.

Fig 3: How do you determine the application rates of pesticides?



Support from Loan Providers:

The table 14 indicates that majority of respondents (90.9%) reported not taking any loans, while a small portion (9.1%) indicated that they had taken loans.

Table 14: Have you taken any loans?

Response	Frequency	Percent
No	409	90.9
Yes	41	9.1
Total	450	100.0

Reasons for taking loan:

The analysis indicates that among respondents who took a loan (8.0%), the primary purposes were to purchase agricultural inputs (8.0%) and to return old loans (0.2%). Other purposes such as land preparation, acquiring a solar water pump, and purchasing livestock were less common, each comprising less than 1% of the responses. The majority (90.9%) did not specify any particular purpose for taking the loan.

Table 15: If YES, what was the purpose of taking the loan?

Response	Frequency	Percent
For land preparation	1	.2
For solar water pump	1	.2

NA	409	90.9
To purchase agri input	36	8.0
To purchase livestock	2	.4
To return old loan	1	.2
Total	450	100.0

Payback Loan status:

The analysis in table 16 indicates that 2.7% reported fully paying back the loan, while 6.4% reported partial repayment.

Table 16: Pay back the loan

Response	Frequency	Percent
Fully pay back	12	2.7
NA	409	90.9
Partially pay back	29	6.4
Total	450	100.0

Access to Agricultural Extension Services:

The analysis of table 17 indicates that a majority of respondents (61.1%) frequently access agricultural extension services. Conversely, a significant portion (34.7%) reported accessing these services rarely, suggesting potential gaps in outreach or availability. Only a small percentage reported either never (3.3%) or occasionally (0.9%) accessing these services.

Table 17: How often do you access agricultural extension services?

Response	Frequency	Percent
Frequently	275	61.1
Never	15	3.3
occasionally	4	0.9
Rarely	156	34.7

What specific information or resources do you feel would assist in adopting BPMs and cultivating biofortified zinc wheat more effectively?

The analysis in table 18 of responses regarding the resources needed for effective adoption and cultivation of biofortified zinc wheat reveals several key insights. Firstly, there is unanimous agreement among respondents on the importance of awareness trainings, provision of certified BZW seed, provision of fertilizers at government rates, and provision of small grants, as evidenced by their 100% response rate. Additionally, a significant proportion of respondents highlighted the importance of support mechanisms such as free pesticides spray and farm tools (88.9%), free zinc wheat seed (84.4%), and provision of training materials for reference (85.8%). Moreover, support for laser leveling to small farmers (78.0%), linking farmers with loan providers (79.1%), and support in pricing of BZW (93.1%) were also deemed essential by a substantial portion of the respondents. However, there was relatively lower emphasis on support for solar tubewells (56.7%) and drilling of underground water bores (1.1%), suggesting that these resources may be perceived as less critical in comparison to other support mechanisms. Overall, the findings underscore the multifaceted nature of resources required for effective adoption and cultivation of biofortified zinc wheat, ranging from educational and training support to access to essential inputs and financial assistance.

Table 18: What specific information or resources do you feel would assist you in adopting and cultivating biofortified zinc wheat more effectively?

Response	Frequency	Percent
Awareness Trainings	450	100.0
Provision of Certified BZW seed	450	100.0
Provision of Free Fertilizers	285	63.3
Support Laser Leveling to small farmers	351	78.0
Provision of free Pesticides spray and farm tools	400	88.9
Free ZINC Wheat Seed	380	84.4
Organizations could link farmers with loan providers	356	79.1
provision of fertilizers on Govt. Rates	450	100.0
Provision of Small Grants	450	100.0
Support in solar tubewell	255	56.7
Underground water boar	5	1.1
Provision of training material for refrence	386	85.8
Support price of BZW	419	93.1

Conclusion

The assessment delves into the adoption and impact of biofortified zinc wheat cultivation in Punjab, focusing on factors influencing adoption, demographic trends, and resource needs. Through surveying 450 farmers across Bahawalpur, Multan, and Khanewal districts, the study

reveals a predominantly young farming workforce engaging in small-scale agriculture. Despite low awareness before project intervention, training initiatives have significantly enhanced farmers' knowledge regarding the nutritional benefits of biofortified zinc wheat. Notably, key agricultural practices like timely sowing and crop rotation have widespread adoption, although challenges persist in adopting certain technologies due to limited access and financial constraints.

The study underscores the pivotal role of factors like enhanced yield, nutritional benefits, and economic considerations in driving technology adoption, highlighting the importance of addressing farmers' concerns regarding productivity and profitability. While the majority of respondents did not take loans, those who did primarily utilized them for purchasing agricultural inputs. Access to agricultural extension services remains relatively frequent, underlining the need for continued support and outreach efforts. Overall, the analysis emphasizes the transformative potential of biofortified zinc wheat cultivation in Punjab, advocating for farmer-centric interventions and multi-stakeholder collaborations to foster sustainable agriculture, improve nutrition outcomes, and enhance rural livelihoods.