FINAL PROGRESS REPORT

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[Role of Hermetic Technology in the Reduction of Postharvest Losses of Biofortified Zinc Wheat In South Punjab]

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1. Research Project Summary

Principal Investigator (PI)	Prof. Dr. Umar Farooq
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Title of the Research Project	Role of Hermetic Technology in the Reduction of Postharvest Losses of Biofortified Zinc Wheat In South Punjab
Project Start Date	01.08.2023
Duration	1 Year
Reporting Period	01.08.2023 to 01-30.07.2024
Approved Budget	3.608 million PKR
Department	Department of Human Nutrition & Dietetics,
University/ Institute	MNS-University of Agriculture, Multan

2. Introduction

In Pakistan, 22.1% of total 207 million people particularly women and children (under 5 years) are Zn deficient. Wheat is a staple food in Pakistan with average daily wheat flour consumption in Pakistan among the highest in the world—at 124 kg per capita per year. It is one of the main agricultural crops in Pakistan, with 80% of farmers growing it on an area of around nine million hectares. Most of the wheat varieties are poor in bioavailable Zn. As a result, biofortified varieties of wheat are potential food vehicles for increasing zinc intakes that could significantly reduce the prevalence of zinc deficiency in the Pakistan population. Currently, there are two main varieties of

Biofortified Zinc Wheat (BZW) in production in Pakistan. Zincol-2016 and Akbar 2019. Additionally, a newer variety, Nawab-2021, has been approved and available more recently for multiplication and to ensure the seed availability for cropping.

With the development Biofortified Zinc Wheat varieties, there is dire need to study their storage shelf life. According to FAO report on review of wheat sector and grain storage issues, Pakistan is suffering from loss of roughly USD 76 to 90 million because of the lack of adequate wheat storage (FAO, 2013). More than 10% quantitative losses in stored wheat have been reported in Pakistan. Quantitative losses are physical and can be measured in weight, while qualitative losses can be assessed in monetary values based on the extent of a specific parameter's deterioration during wheat storage (e.g. deterioration of wheat seed germination and gluten quality).

In Pakistan, the various wheat storage methods that are in use by the public and private sector include House Type Godowns, Concrete/Steel/Grain Silos, Bulk Head, Bini Shells, Hexagonal Shells, Open Bulk Heads, Open Storages etc. In case of farmers, majority of them are using baskets, underground storage, polypropylene bags, Jute bags, Mud Storages, Brick and Cement Silos, Iron Silos and Bins etc. In a comparative study held by Spate Irrigation Network on various conventional storages used in Pakistan, it was found that almost all the conventional stores cannot keep the grains safe from infestation by insects etc. However, we found a lot of evidence in favor of hermetic storage being more effective as compared to other storage methods/technologies globally. Use of hermetic storage containers is a green alternative for safe storage of paddy rice, for 12 months without application of pesticides, bringing multiple advantages for smallholder farmers, lever food security and income generation for smallholder farmers and rice milling companies (Covele et al., 2020). In another evaluation study held on different grain storage technologies against storage insect pests over an extended storage time, it was found that the conventional storage methods, particularly jute sack, did not protect the grains from insect damage and nutritional losses. However, all the hermetic storage methods showed better storage performance in retaining germination capacity, nutritional composition and reduced the percentage of seed damage (Kuyu et al., 2022).

Seed moisture contents, temperature and relative humidity of storage environment are important factors that determine the extent of both quantitative and qualitative losses during storage. High seed moisture is the main culprit of seed deterioration (Bradford et al., 2018) and studies have suggested that high moisture content during storage is responsible for seed aging, storage insect pests, aflatoxin contamination and loss in nutritional components that affect product quality (Afzal et al. 2017). Use of hermetic storage bags help to retrain low seed moisture particularly during humid months and thus have been proven effective for storage of maize (Bakhtavar et al., 2019a). Hermetic storage technology has shown its potential for reducing the post-harvest losses in different cereal grains. It is effective, green, low cost and easy to adopt technology (Baribusta and Nojoroge, 2020). It is widely used in several countries/regions having humid environment; however, it is not widely known, adopted and accessible to farmers in Pakistan.

Main reason of low adaptability is the lack of awareness about the benefits of hermetic storage technology in the farming community. Although few commercial companies introduced the technology, it is used on a limited scale by importing hermetic structures (sacks and cocoons). Once filled and closed they are hermetic so that when filled with grain a modified atmosphere is created after some weeks that kills the insect pests. Cocoons are available in capacities ranging from 1 to 300 tonnes and can be purchased with a shelter to screen them from direct sunshine from outside. Now a days, few of the local companies are also manufacturing these hermetic storage bags, however there is less demand and lack of evidence at local level on its commercial viability.

Therefore, through this study/work we intend to investigate the effectiveness of hermetic technology and its comparison with the conventional storage techniques with wheat grains and seeds. We also intend to evaluate the impact of hermetic storage on the wheat seed germination, nutrient's availability (especially Zinc & Iron) and its impact on product quality.

3. Materials & Methods

This project was executed by involving the small holder farmers in Khanewal and Multan districts. Wheat seed of selected varieties were stored at the common storehouse of the 4 different farmers at 4 different locations of Multan and Khanewal district using local hermetic seed storage technology.

Factors studied

A. **Wheat Seed Type**

Biofortified Zinc Wheat

- Akbar 2019
- Nawab 2021

Non Biofortified Zinc Wheat

- Dilkash 2020
- Urooj 2022

B. **Storage Type**

- Conventional storage in polypropylene bags
- Conventional storage in jute bags
- Storage in locally manufactured hermetic bags
- Storage in imported hermetic bags

C. **Storage Location**

- Multan
- Khanewal

Parameters Studied

Seed Quality

- **Seed moisture**

  Seed moisture is an important parameter of seed quality. Seed's storge life is mainly dependent upon the seed moisture contents. High seed moisture speeds up the process of seed deterioration and reduces the seed germination potential.

Moreover, the attack of stored grain pests, storage fungi and bacteria is directly linked with high seed moisture contents.

- **Seed germination**

  Seed germination test is the most widely used and universally accepted method to determine the seed quality. One of the main objective of seed storage is to retain high seed germination at the end of storage period. So testing seed germination is the most reliable tool to determine the effectiveness of any storage technology.

- **Electrical conductivity of seed leachates**

  Seed vigor is the potential activity and performance of a seed lot under wide range of sowing conditions particularly under stress conditions. Vigorous seeds have high seed germination and uniform seedling growth. Measuring electrical conductivity of seed leachates is the recommended method of the International Seed Testing Association to determine seed vigor. Higher electrical conductivity of seed leachates indicates high rate of seed deterioration and less seed vigor.

- **Storage losses due to stored grain pests**

  Several storage pests attack on the cereal and pulses seed during storage. Storage technologies are evaluated based on their potential to limit both qualitative and quantitative storage losses.

- **Stored grain insect pest infestation**

  Stored grain insect pests including lesser grain borer, khapra beetle, red flour beetle, weevils population indicates the level of insect pest infestation and relates with the storage losses.

Nutritional composition

- **Aflatoxin contamination**

  Aflatoxin contamination was analyzed using commercially available aflatoxin kit (Zokeyo) following manufacturer's protocol. For this purpose, wheat grains were crushed into fine flour and sieved using a 20mesh sieve. Five grams of sieved flour was added in 25 mL of extraction buffer followed by a 5minute incubation. The mixture was centrifuged at 4500rpms for 5 minutes and supernatant was carefully transferred to presterilized falcon tube (50 mL). Dilution of the supernatant was carried out by adding diluent buffer with a dilution factor of 12.5. ELISA plate wells precoated with antibodies were loaded with 50uL of diluted samples and controls (0ppb, 0.15ppb, 0.4ppb, 1ppb and 2.5ppb) with 3 replications. The enzyme labelled substance and anti -reagent (50uL) was dispensed in each well and mixed thoroughly followed by covering and an incubation of 30 minutes at room temperature. The plate was then rinsed 3 to 4 times by washing solution and the plate was dashed presterilized filter paper for removal of washing buffer followed by a 5 minutes incubation at room temperature for air drying. Substrate solution (100uL) was then added in each well and the plates were wrapped and incubated again for 15 minutes in dark. Stop solution (100uL) was then added in each well and the plate was read in an ELISA plate reader at 450nm wavelength.

- Thousand kernel weight
- Test weight
- Moisture content
- Crude protein
- Crude Ash
- Crude fiber
- Crude fat
- Minerals (Fe, & Zn)
- Gluten content (Wet & Dry)
- Rheology of flour
- Product preparation and sensorial acceptance
- Mineral (Fe and Zn) in product

Economic Analysis

- ROI
- Cost Benefit Ratio

Technical approach

We have adopted following approached to maximize the benefits of the project and to ensure its relevance and benefit to small scale farmers and to enhance the chance of adoption:

1. Research for facts: Research was carried out with a 2 x 2 x 2 structure; 2 types of wheat varieties (conventional and biofortified), 2 types of storage (conventional and hermetic), and 2 types of hermetic structures (local and imported). The aim was to test the hypothesis that the bundling of two innovations (bio fortification plus hermetic storage) compared to the use of conventional grains and storage solutions: reduced post-harvest losses (kg), improve seed quality (nutrient retained, seed germination), improve food safety (aflatoxins) and minimum damage to nutritional quality & product preparation potential in a more cost-effective way.

2. Participatory approach for relevance: We executed the project with the involvement of small scale farmers to understand their motivation to move to action: i) farmers receive seeds with higher germination rates and will have higher yields, and sell more; ii) farmers' cooperatives/small holder farmers can prevent post- harvest losses and rush selling and can get better prices of their produce; iii) small processors and millers can get nutrients enriched, safe and high-quality grains and can get more profit; and iv) consumers can access to safe (free from chemicals/aflatoxins etc.), nutritious (biofortified wheat) which will improve their health and nutritional outcome.

3. Inspire for action: Results of the research were disseminated to highlight the benefits of the hermetic storage technology to the relevant stakeholders not only to build awareness and generate demand, but also to enhance the advocacy and policy-informing mechanism.

The major tasks included:

1. Designed and conducted a research study in a scientific manner to see the impact of bio fortification and hermetic storage.
2. Provided technical support to GAIN & its implementing partners (AGAHE) in the field for the introduction and care of hermetic storage bags and collection of research data.
3. Training of farmers working for seed multiplication to use the hermetic bags for wheat seed storage. The organizing training events was the responsibility of

GAIN & its implementation partners and MNSUAM team provided resource persons for training.

4. Conducted the pre storage & after storage lab test for different parameters like moisture content, germination, vigor, quantitative losses, pest infestation rate, physical characteristics, compositional analysis, rheology of flour, product potential.
5. Draw all possible comparison of all tests and generate evidence
6. Developed a detailed study report with the key recommendations for scaling of usage of Hermetic Technology in Pakistan for Biofortified Zinc Wheat.
7. Publication of the article in a scientific journal is in progress.

4. Seed Sampling & Measurements

Initial sampling has been done to determine seed and nutritional quality parameters. After that seed have been stored at designated locations of the farmers. Seed sampling have been done in the month of October (after 2-month storage), December (after 4-month storage), February (after 6-month storage) to access the following seed and nutritional quality.

Seed Quality

- Seed moisture

Seed moisture contents were determined by using digital moisture meter Minijack, USA.

- Seed germination

The seed germination percentage was estimated according to the protocol mentioned by International Seed Testing Association (ISTA, 2018). Seed germination was calculated by using the following formula,

$$\text{Germination Percentage (\%)} = \frac{\text{No. of Seed Germinated}}{\text{Total No. of Seed}} \times 100$$

- Electrical conductivity of seed leachates

The electric conductivity of the seed samples was calculated by soaking 50 seeds of each treatment in a 250 ml distilled water and kept the seeds for 24 hours in the germination chamber. After 24 hours. The electrical conductivity of seed leachates was measured using a conductivity meter (HANNA: H19813-5) and the conductivity per gram of seed mass was calculated (µS cm-1g-1) and recorded. EC of seed was calculated by using the following formula

$$\text{Conductivity} = \frac{\text{Conductivity reading} - \text{background reading}}{\text{Weight of replicates (g)}}$$

Nutritional composition and aflatoxin contamination

- Thousand kernel weight
- Test weight
- Moisture content
- Crude protein
- Crude Ash
- Crude fiber
- Crude fat
- Minerals (Fe, & Zn)
- Gluten content (Wet & Dry)
- Rheology of flour
- Product preparation and sensorial acceptance
- Mineral (Fe and Zn) in product

5. Results of Initial Seed Quality Analysis

5.1 Initial Seed Moisture Contents (%)

Initial seed moisture contents of the wheat varieties were determined before execution of storage experiment. Results indicated that highest seed moisture contents (10.54%) were recorded for biofortified wheat variety Nawab-21. Lowest seed moisture contents were recorded for non biofortified wheat variety Dilkash-20 (Fig.1).

5.2 Initial Seed Germination (%)

Results of initial seed germination of the wheat varieties determined before execution of storage experiment indicated that highest seed germination (%) were recorded for non biofortified wheat Dilkash-20. Lowest seed moisture contents were recorded for biofortified wheat variety Nawab-21 (Fig. 2).

5.3 Electrical Conductivity of Seed Leachates (μS cm^{-1} g^{-1})

Seed vigor in terms of electrical conductivity of seed leachates (μS cm^{-1} g^{-1}) of the wheat varieties determined before execution of storage experiment. Results indicated that highest value of electrical conductivity of seed leachates was given by the Nawab-21 while lowest electrical conductivity of seed leachates was recorded for Dilkash-20 (Fig. 3).

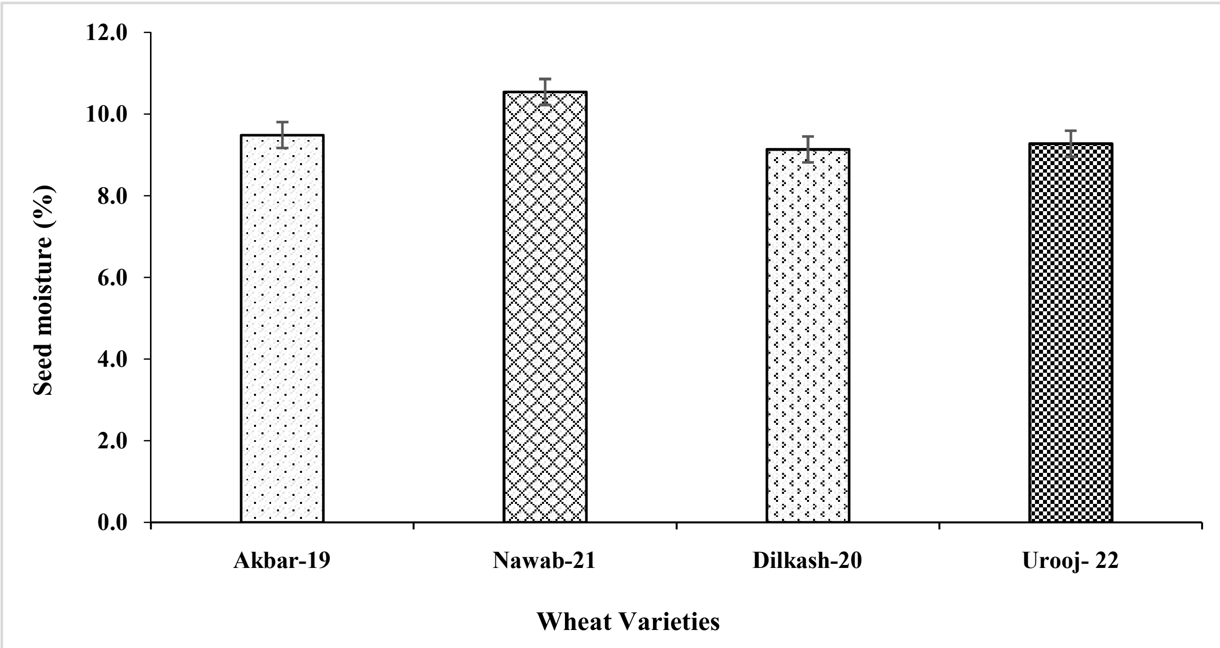


Figure 1. Initial seed moisture contents (%) of wheat varieties before storage

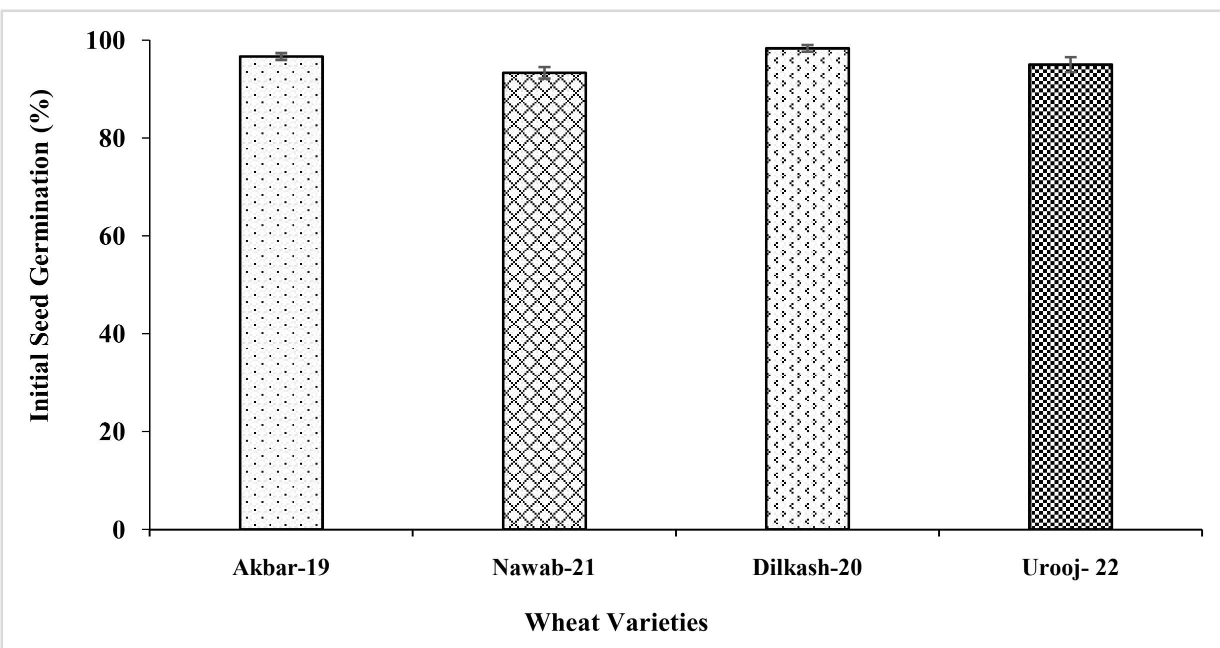


Figure 2. Initial seed germination (%) of wheat varieties before storage

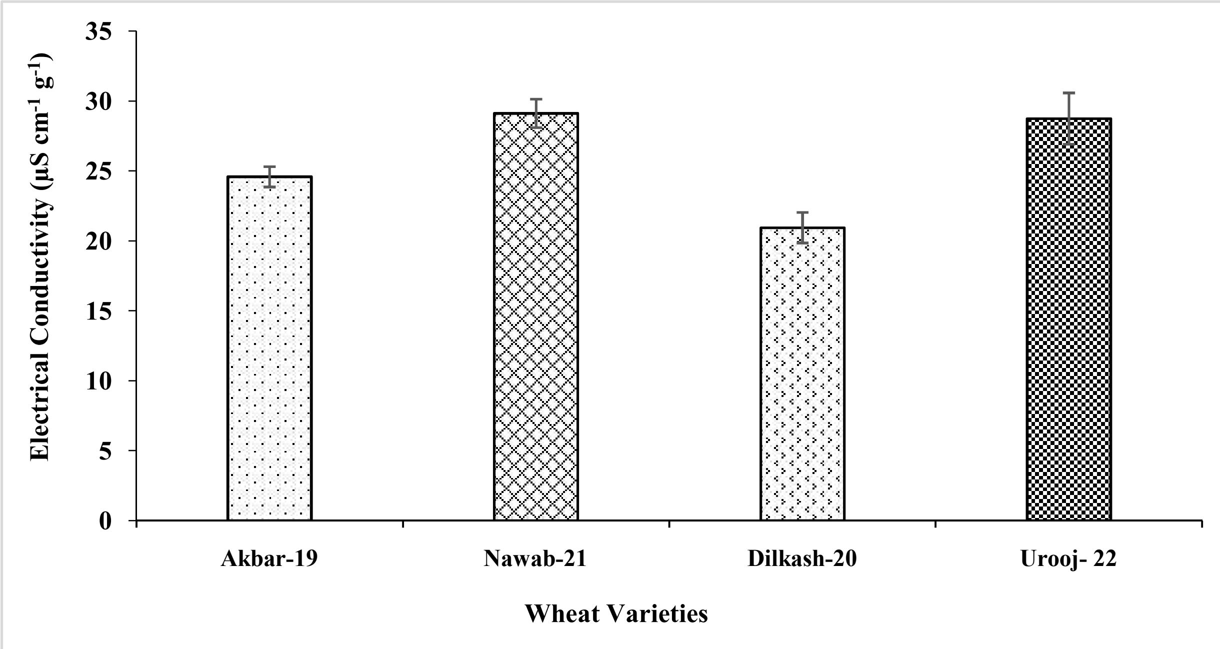


Figure 3. Seed vigor in terms of electrical conductivity (µS cm^{-1} g^{-1}) of seed leachates of wheat varieties before storage

6. Results of seed quality parameters after storage

6.1 Seed moisture (%)

Initial seed moisture contents of Akbar-19 were 9.48% before storage. Periodic data of seed moisture was recorded for the period of 12 months storage. After 12-month storage (Figure 4), moisture of Akbar-19 increased to 12.08% in iron silo while minimum seed moisture content (9.37%) was recorded from the seed stored in imported hermetic bag. At Multan, maximum seed moisture contents (13.32%) were recorded for the seed stored in in iron silos. Minimum seed moisture contents (9.52%) were recorded in local hermetic bag. At Khanewal location I maximum seed moisture contents (12.31%) were recorded from the seeds stored in iron silo. Minimum seed moisture content (9.62%) was recorded from the seeds stored in local hermetic bag. At Khanewal location II, maximum seed moisture contents were recorded from the seeds stored in PP bag while minimum seed moisture contents were recorded for the seed stored in imported hermetic bag (Figure 4-7).

Initial seed moisture contents of Nawab-21 were 10.54% before storage. Periodic data of seed moisture was recorded for the period of 12 months storage (Figure 4-7). After 12-month storage (Figure 4), moisture increased to 12.41% in iron silo while minimum seed moisture content (10.50%) was recorded from the seed stored in imported and local hermetic bags. At Multan, maximum seed moisture contents (15.11%) were recorded for the seed stored in PP bags while minimum seed moisture contents (10.5%) were recorded in local hermetic bag (Figure 4-7). At Khanewal location I maximum seed moisture contents (13.69%) was recorded in iron silo while minimum seed moisture content (10.09%) was recorded from the seeds stored in imported hermetic bags. At Khanewal location II, maximum seed moisture contents were recorded (13.62%) in iron silo while minimum seed moisture contents were in local hermetic bag (10.24%).

Dilkash-20 had the initial moisture contents up to (9.13%). After 12 months of storage period location of Jalalpur had maximum moisture contents (11.57%) in seed stored in iron silos while minimum recorded in imported hermetic bags (9.64%). Multan location had maximum moisture contents in iron silo (12.96%) while minimum (9.67%) recorded in imported hermetic bags. Khanewal location I had minimum moisture contents in seed (Figure 4-7), stored in imported hermetic bags (9.49%) while maximum recorded in PP bags (12.36%). Highest moisture contents were (12.95%) of seed stored in PP bags while lowest moisture was recorded in imported hermetic bags (9.23%).

The initial moisture contents of Urooj-22 were (9.27%) at the time of storage. After 12-month of storage period, location of Jalalpur had maximum moisture contents (11.49%) of seed stored in PP bags while lowest moisture (9.37%) was recorded in imported hermetic bags (Figure 4-7). Multan location had highest moisture contents in iron silo (13.27%) while lowest was recorded in imported hermetic bags (9.45%). Khanewal location I, had maximum moisture contents in iron silos (11.98%) while minimum moisture was recorded in imported hermetic bags (9.58%). In case of Khanewal location II, maximum moisture was recorded in PP bags (11.61%) while minimum moisture was recorded in imported hermetic bag (9.30%) after 12 months storage period.

6.2 Seed germination (%)

Results of seed germination varied in different storage structures after 12 months storage. Initially Akbar-19 had (98.3%) germination. At Jalalpur, the highest germination (88.3%) was recorded for the seed stored in local hermetic bags while lowest germination (80%) was recorded for the seed stored in PP bags and iron silos (Figure 8). At Multan, hermetic bags had the highest germination percentage (91.6%) while minimum germination (75%) was recorded in iron silos (Figure 9). At Khanewal location I, the highest seed germination (88.3%) was recorded for the seed stored in both local and imported hermetic bags while lowest was (60%) stored in PP bags (Figure 10). The lowest germination percentage (73.3%) recorded in iron silos while highest (86.6%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 8-11).

Seed germination varied in different storage structures after 12 months storage. Initially Nawab-21 had (95%) germination. At Jalalpur location after 12 months sampling interval the highest germination (81.6%) was in imported hermetic bags while lowest germination (53.3%) was stored in PP bags (Figure 8). At Multan, imported hermetic bags had the highest germination percentage (88.3%) while minimum germination (60%) was recorded in iron silos (Figure 9). Khanewal location I, had the highest seed germination (78.3%) in imported hermetic bags while lowest was (53.6%) stored in iron silo (Figure 10). The lowest germination percentage (75.3%) recorded in PP bags while highest (83.3%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 8-11).

Germination percentage varied in different storage structures after 12 months storage. Initially Dilkash had (98.3%) germination. At Jalalpur location after 12 months sampling interval the highest germination (88.3%) was in imported hermetic bags while lowest germination (85%) was stored in PP bags and iron silos (Figure 8). At Multan, hermetic bags had the highest germination percentage recorded in both local and imported hermetic bags (90%) while minimum germination (64.6%) was recorded in PP bags (Figure 9). Khanewal location I, had the highest seed germination (91.6%) in imported hermetic bags while lowest was (58.3%) stored in iron silo (Figure 10). The lowest germination percentage (74.6%) recorded in iron silos while highest (88.3%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 8-11).

Initially Akbar-19 had (98.3%) germination. At Jalalpur location after 12 months sampling interval the highest germination (90%) was in local hermetic bags while lowest germination (83%) was stored in PP bags and iron silos (Figure 8). At Multan, both hermetic bags had the highest germination percentage (91.6%) while minimum germination (60.6%) was recorded in PP bags (Figure 9). Khanewal location I, had the highest seed germination (91.6%) in both types of hermetic bags (imported and local) while lowest was (69%) stored in PP bags (Figure 10). The lowest germination percentage (76.6%) recorded in iron silos while highest (88.3%) in both local and imported hermetic bags at Khanewal location II after 4th sampling (Figure 8-11).

6.3 Electrical conductivity of seed leachates (µS $cm^{-1}g^{-1}$)

Initial Electrical conductivity (EC) of Akbar-19 were (32.2 µS $cm^{-1}g^{-1}$) before storage. Periodic data of seed EC was recorded for the period of 12 months storage. After 12-month storage, EC of Akbar-19 increased to (65.6 µS $cm^{-1}g^{-1}$) in PP bags while minimum seed EC (33 µS $cm^{-1}g^{-1}$) was recorded from the seed stored in imported hermetic bag. At Multan, maximum EC (63.6 µS $cm^{-1}g^{-1}$) were recorded for the seed stored in in iron silos. Minimum EC (36.3 µS $cm^{-1}g^{-1}$) were recorded in imported hermetic bag. At Khanewal location I maximum EC (47.6 µS $cm^{-1}g^{-1}$) were recorded from the seeds stored in iron silo. Minimum EC (36.1 µS $cm^{-1}g^{-1}$) was recorded from the seeds stored in imported hermetic bag. At Khanewal location II, maximum EC were recorded (61.6 µS $cm^{-1}g^{-1}$) from the seeds stored in iron silo while minimum EC were recorded for the seed (33.9 µS $cm^{-1}g^{-1}$) stored in local hermetic bag (Figure 12-15).

Initial seed Electrical conductivity (EC) of Nawab-21 were (37 µS $cm^{-1}g^{-1}$) before storage. Periodic data of EC was recorded for the period of 12 months storage (Figure 4-7). After 12-month storage, EC increased to (67.2 µS $cm^{-1}g^{-1}$) in iron silo while minimum seed EC (37.6 µS $cm^{-1}g^{-1}$) was recorded from the seed stored in imported hermetic bags. At Multan, maximum seed EC (69.7) were recorded for the seed stored in iron silo while minimum seed EC (42.6) were recorded in imported hermetic bag (Figure 4-7). At Khanewal location I maximum EC (55.8 µS $cm^{-1}g^{-1}$) was recorded in iron silo while minimum seed EC (41.5) was recorded from the seeds stored in imported hermetic bags (Figure 12-15). At Khanewal location II, maximum seed EC were recorded (62.9 µS $cm^{-1}g^{-1}$) in iron silo while minimum seed EC were in local hermetic bag (38.4 µS $cm^{-1}g^{-1}$).

Dilkash-20 had the EC up to (26.9 µS $cm^{-1}g^{-1}$). After 12 months of storage period location of Jalalpur had maximum EC (69.5 µS $cm^{-1}g^{-1}$) in seed stored in iron silos while minimum recorded in imported hermetic bags (36.9 µS $cm^{-1}g^{-1}$). Multan location had EC in iron silo (63.5 µS $cm^{-1}g^{-1}$) while minimum (29.8 µS $cm^{-1}g^{-1}$) recorded in imported hermetic bags. Khanewal location I had minimum EC in seed, stored in imported hermetic bags (27.5 µS $cm^{-1}g^{-1}$) while maximum recorded in iron silo (55.8 µS $cm^{-1}g^{-1}$). Highest EC were (56.8 µS $cm^{-1}g^{-1}$) of seed stored in PP bags (Figure 12-15) while lowest moisture was recorded in imported hermetic bags (27.6 µS $cm^{-1}g^{-1}$).

The initial EC of Urooj-22 were (34.6 µS $cm^{-1}g^{-1}$) at the time of storage. After 12-month of storage period, location of Jalalpur had maximum EC (66.6 µS $cm^{-1}g^{-1}$) of seed stored in iron silo while lowest EC (34.7 µS $cm^{-1}g^{-1}$) was recorded in imported hermetic bags. Multan location had highest EC in iron silo (60.8 µS $cm^{-1}g^{-1}$) while lowest was recorded in imported hermetic bags (39 µS $cm^{-1}g^{-1}$). Khanewal location I, had maximum EC in PP bag (57.7 µS $cm^{-1}g^{-1}$) while minimum EC was recorded in imported hermetic bags (36.7 µS $cm^{-1}g^{-1}$). In case of Khanewal location II, maximum EC was recorded in iron silo (57.4 µS $cm^{-1}g^{-1}$) while minimum moisture was recorded in imported hermetic bag (37.1 μS $cm^{-1}g^{-1}$) after 12 months storage period (Figure 12-15).

6.4 Grain damage (%)

The grain damage percentage was calculated in the final sampling. Grain damage (%) was negligible (0%) in all four wheat verities that were stored in imported hermetic bags and hermetic drum at Jalalpur location. Maximum grain damage (54.5%) was observed in Nawab-21 stored in iron silos. Akbar-19 had maximum grains damaged (45.5%) in iron silo. Maximum grains of Dilkash-20 (36.6) and Urooj-22 (35.3%) were damaged in PP bags (Figure 16). At Multan location, minimum grain damage was observed in imported hermetic, local hermetic bags and hermetic drum while maximum 64.5% damage occurred in Nawab-21 stored in iron silos. Akbar-19 had maximum grains damaged (52%) in iron silo. Maximum grains of Dilkash-20 (34.6) and Urooj-22 (33%) were damaged in PP bags and iron silo respectively (Figure 17). At Khanewal location I, minimum grain damage was observed in imported hermetic bags, local hermetic bags and hermetic drum while maximum 66% damage recorded in Nawab-21 stored in iron silos. Akbar-19 had maximum grains damaged (44.5%) in PP bag. Maximum grains of Dilkash-20 (31.6) and Urooj-22 (35.3%) were damaged in PP bags (Figure 18). At Khanewal location II, minimum grain damage was observed in imported hermetic bags, local hermetic bags and hermetic drum while maximum 60% and 54.2% damage recorded in Nawab-21 and Akbar-19 respectively when stored in PP bags. Maximum grains of Dilkash-20 were damaged (40%) in PP bags whereas maximum damaged grains percentage (37.3) of Urooj-22 was recorded in iron silo (Figure 19).

6.5 Weight loss (%)

At Jalalpur location, weight losses after seed storage in Akbar-19 were maximum (24%) for the seed stored in iron silos whereas minimum weight losses (0.02%) were recorded in imported hermetic bags and hermetic drums. Nawab-21 had 31.4% weight losses when stored in iron silo while minimum weight losses were recorded in imported hermetic bags and hermetic drums (0.03%). Maximum weight losses in Dilkash-20 were observed in iron silo (19.3%) whereas minimum weight losses (0.01%) were observed in imported hermetic bags and hermetic drums. Urooj-22 had the highest weight losses (21.6%) in PP bags while 0% weight losses were observed in imported hermetic bags and hermetic drums (Figure 20). At Multan location, weight losses after seed storage in Akbar-19 were maximum (26.9%) for the seed stored in iron silos whereas minimum weight losses (0.02%) were recorded in imported hermetic bags and hermetic drums. Nawab-21 had 30.3% weight losses when stored in iron silo while minimum weight losses were recorded in imported hermetic bags and hermetic drums (0.02%). Maximum weight losses in Dilkash-20 were observed in iron silo (20.6%) whereas minimum weight losses (0.01%) were observed in hermetic drums. Urooj-22 had highest weight losses (20.5%) in iron silo while 0% weight losses were observed in imported hermetic bags and hermetic drums (Figure 21). At Khanewal location I, weight losses in Akbar-19 were maximum (24%) for the seed stored in iron silos whereas minimum weight losses (0.01%) were recorded in imported hermetic bags and hermetic drums. Nawab-21 had 30.9% weight losses when stored in iron silo while minimum weight losses were recorded in imported hermetic bags and hermetic drums (0.02%). Maximum weight losses in Dilkash-20 were observed in iron silo (20.3%) whereas minimum weight losses (0.01%) were observed in imported hermetic bags and hermetic drums. Urooj-22 had the highest weight losses (20.9%) in iron silo while 0% weight losses were observed in hermetic drums (Figure 22). At Khanewal location II, weight losses in Akbar-19 were maximum (24.5%) for the seed stored in iron silos and PP bags whereas minimum weight losses (0.04%) were recorded in imported hermetic bags and hermetic drums. Nawab-21 had 29.8% weight losses when stored in iron silo while minimum weight losses were recorded in imported hermetic bags and hermetic drums (0.1%). Maximum weight losses in Dilkash-20 were observed in iron silo (20.7%) whereas minimum weight losses (0.07%) were observed in imported hermetic bags and hermetic drums. Urooj-22 had the highest weight loss (20.5%) in PP bags and iron silo while 0.04% weight losses were observed in imported hermetic bags and hermetic drums (Figure 23).

6.6 Aflatoxins contamination

Aflatoxins contamination was only found in traces, but no contamination observed in imported and local hermetic bags in all four wheat varieties. At Jalalpur Pirwala Nawab-21 stored in polypropylene bags and iron silos had only 0.03 and 0.04 ppb mycotoxins contents respectively after 4^{th} sampling (Figure 24). In case of Multan, they were 0.07 and 0.08 in Nawab-21 stored in PP bags and iron silos (Figure 25). In Khanewal district at location-1, no contaminants were recorded in both hermetic bags while found 0.06 to 0.07ppb in seed, stored in PP bags and iron silos (Figure 26). The location-2 Khanewal had maximum contamination up to 0.07ppb in Nawab-21 stored in PP bags and iron silos (Figure 27).

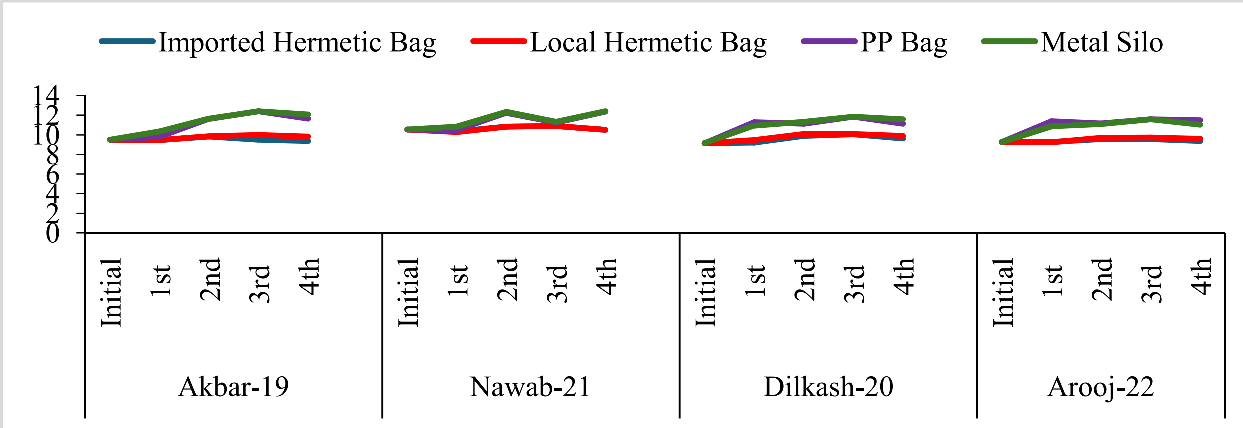


Figure 4 Moisture % at Jalalpur Pirwala

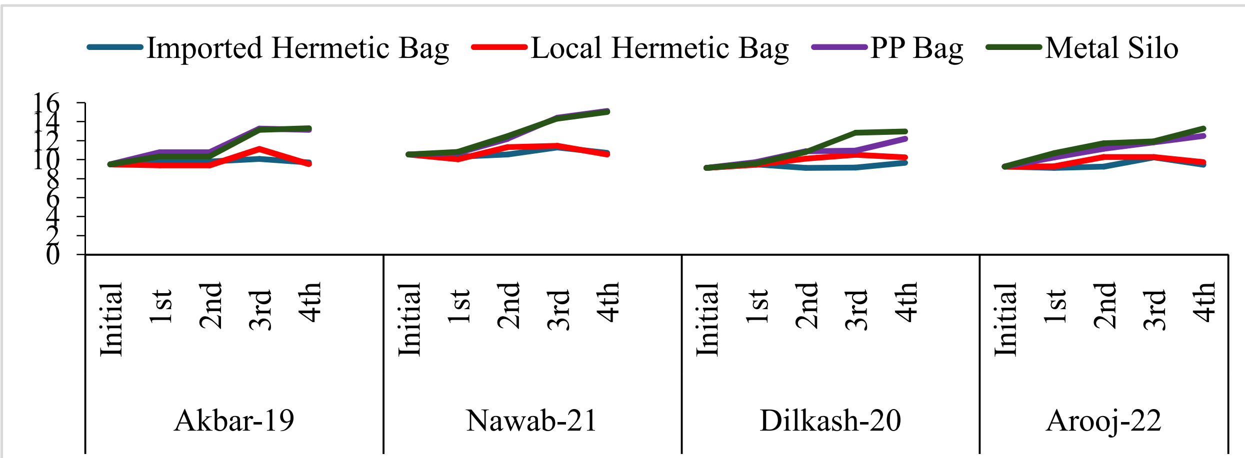


Figure 5 Moisture % at Multan

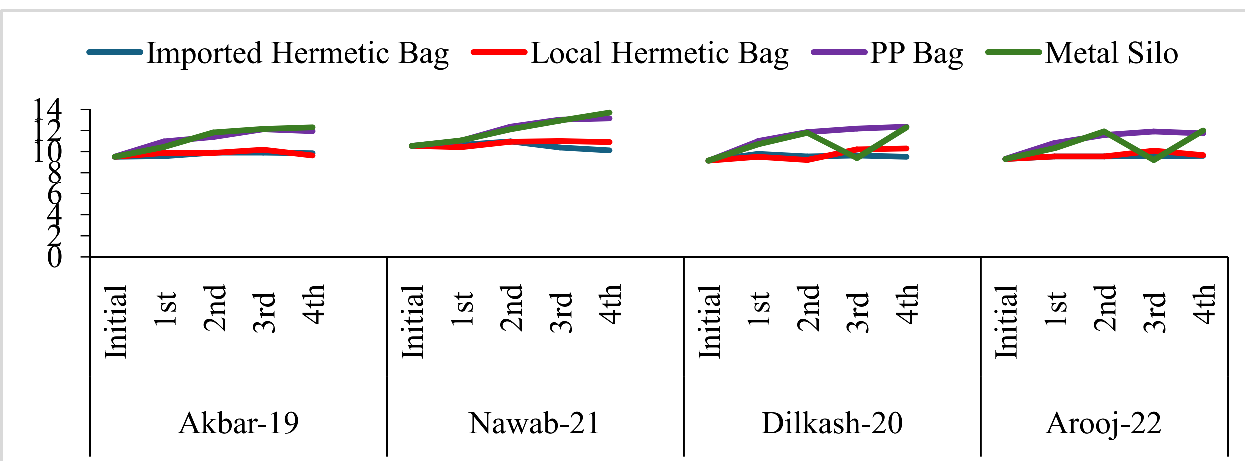


Figure 6 Moisture % at Khanewal location-1

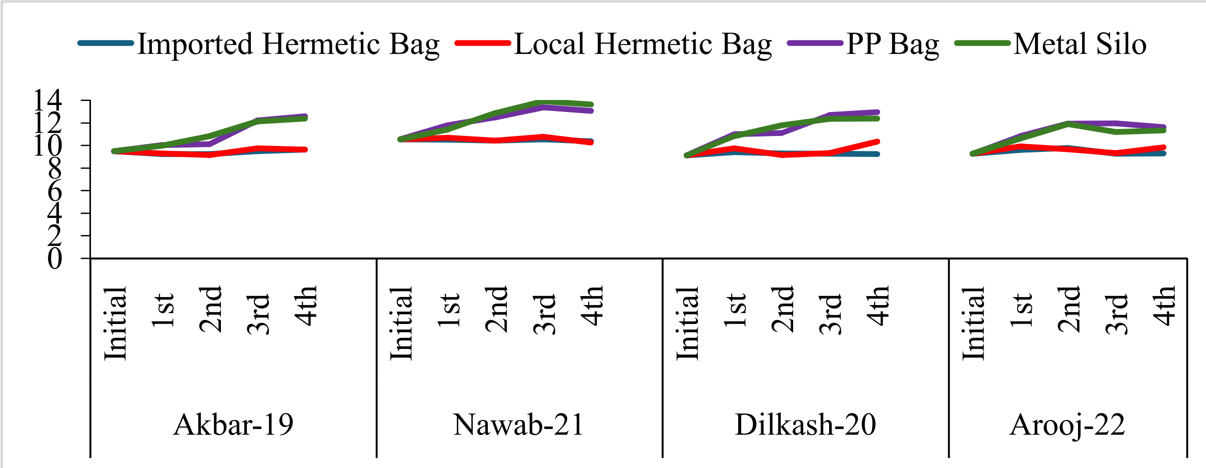


Figure 7 Moisture % at Khanewal location-2

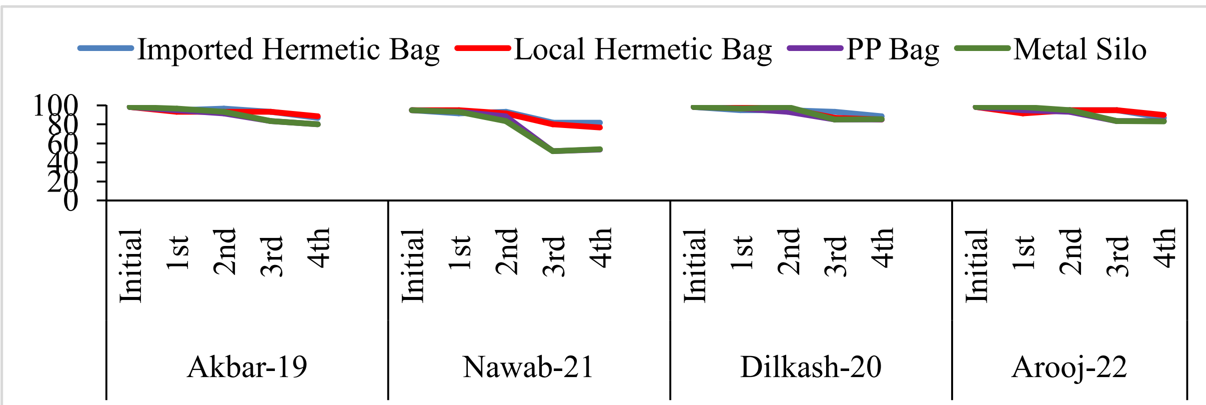


Figure 8 Germination % at Jalalpur Pirwala

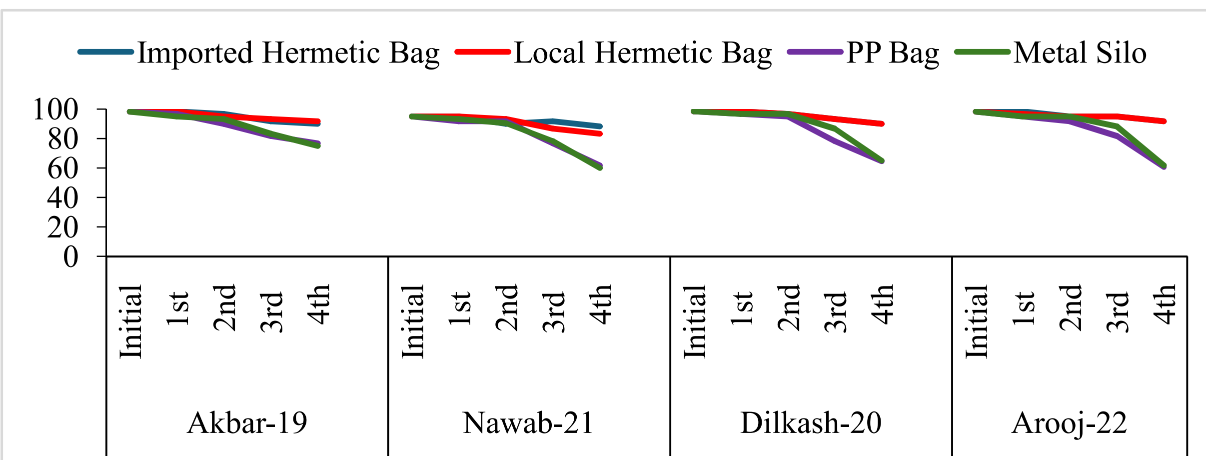


Figure 9 Germination % at Multan

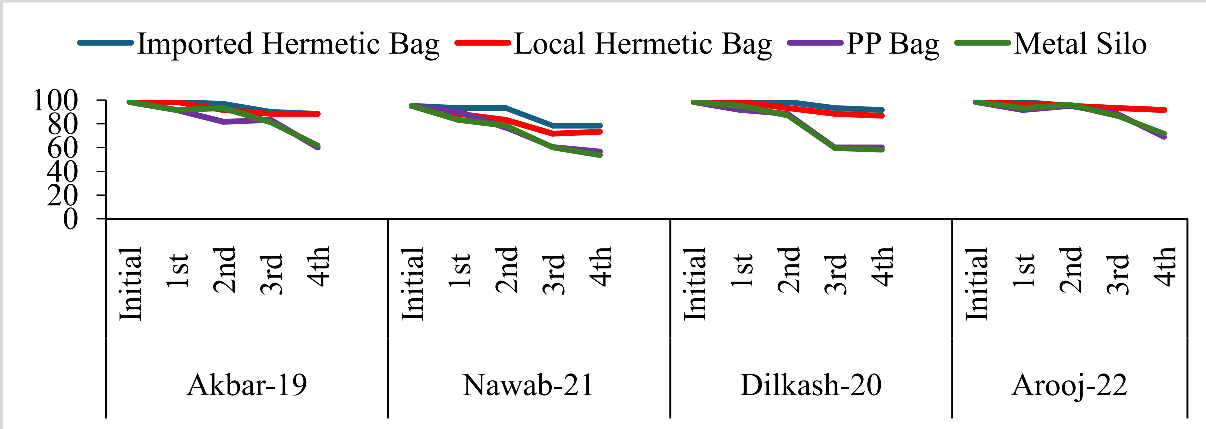


Figure 10 Germination % Khanewal location-1

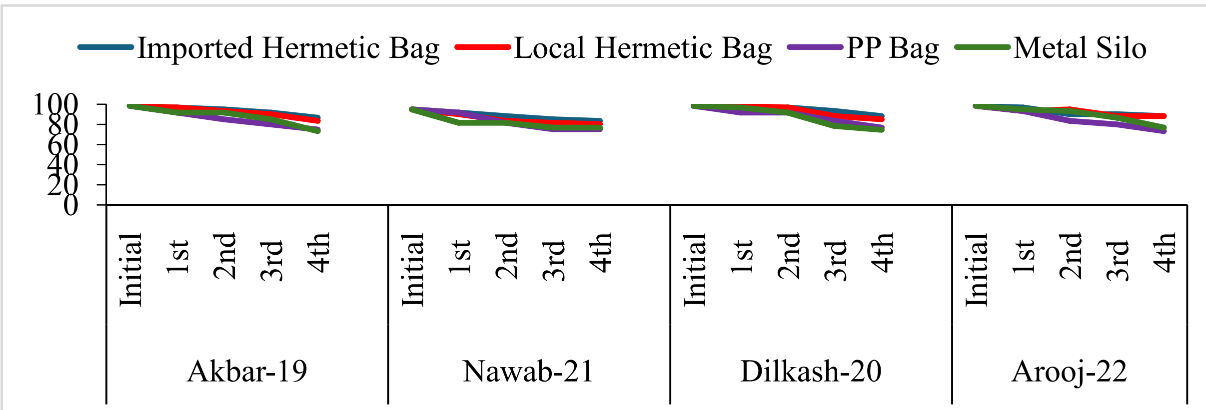


Figure 11 Germination % at Khanewal location-2

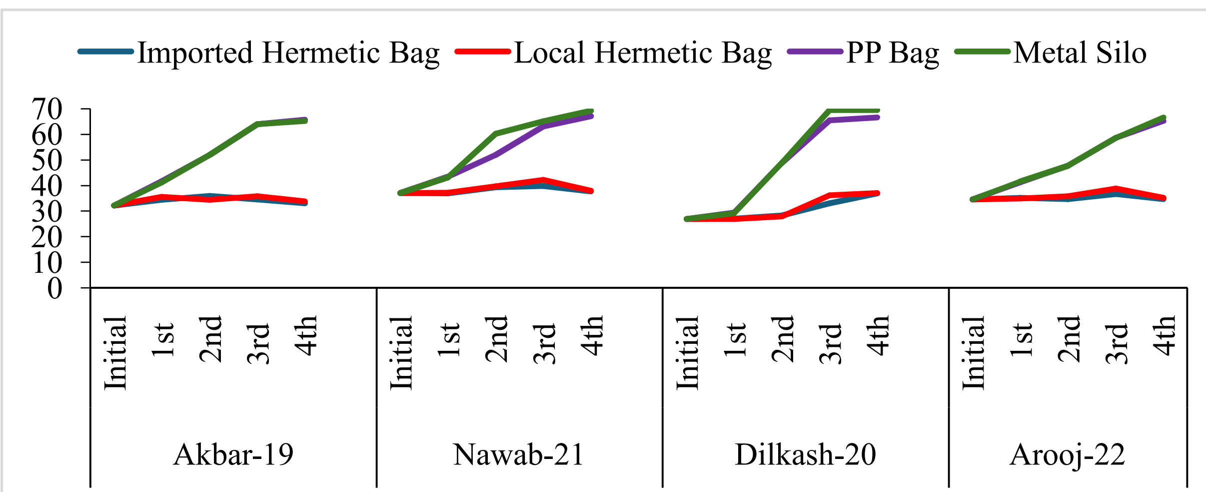
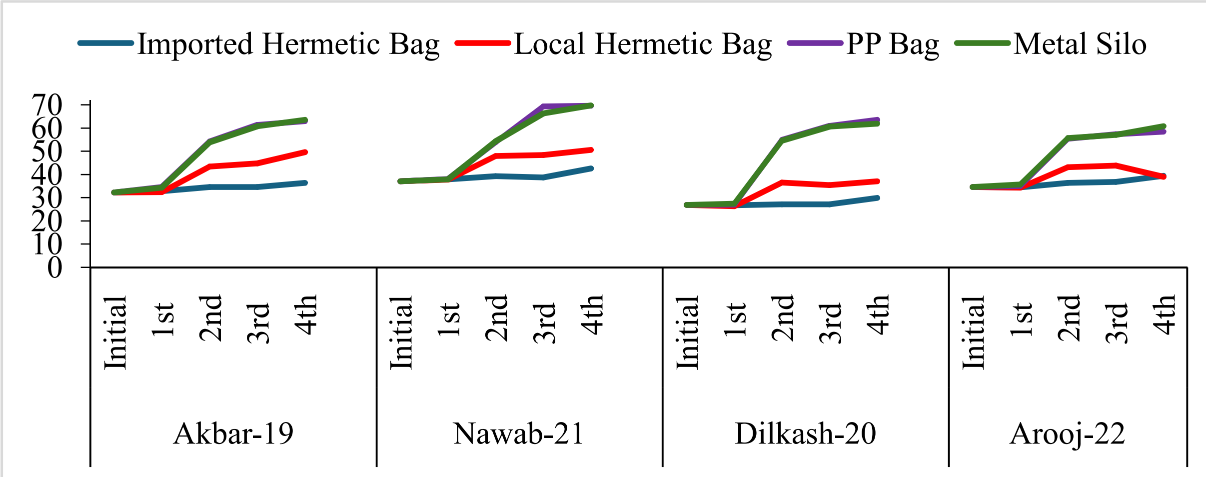


Figure 12 Electrical conductivity at Jalalpur Pirwala



s

Figure 13 Electrical conductivity % at Multan

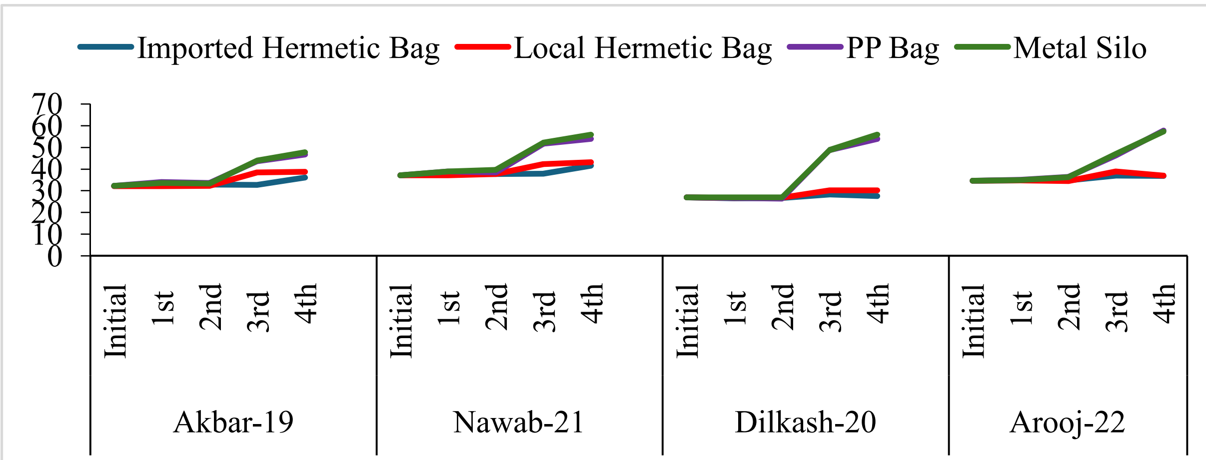


Figure 14 Electrical conductivity at Khanewal location-1

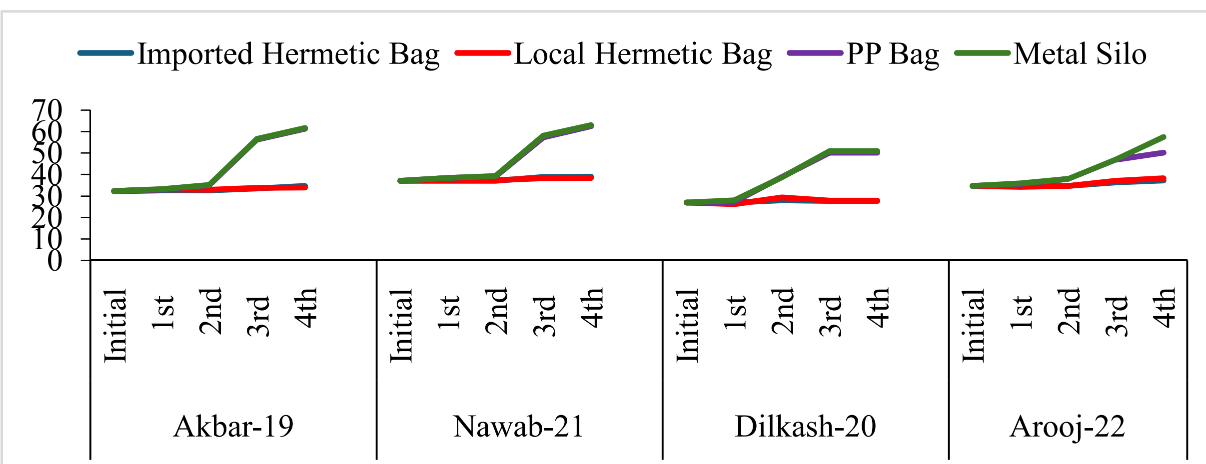


Figure 15 Electrical conductivity at Khanewal location-2

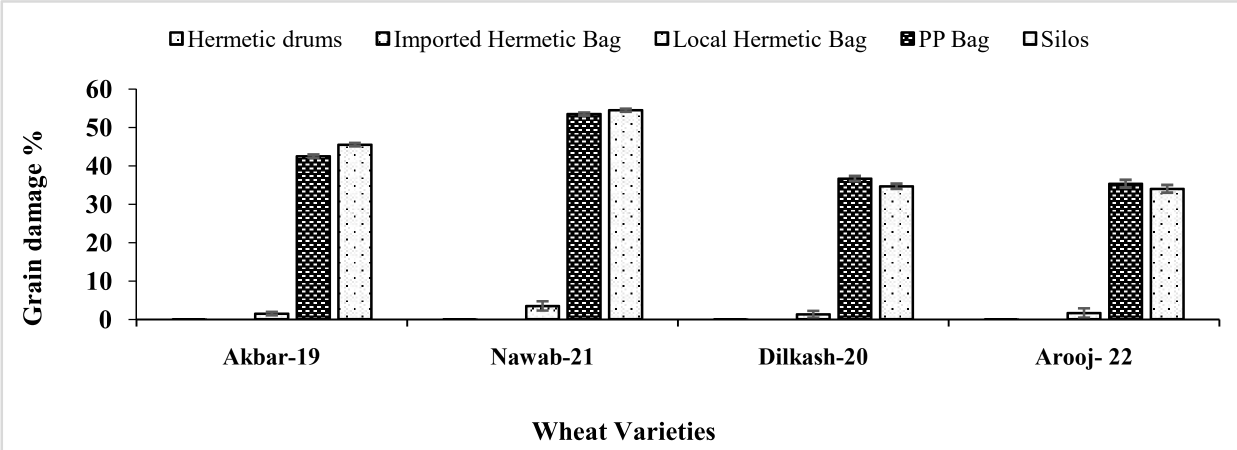


Figure 16 Grain damage (%) at Jalalpur Pirwala

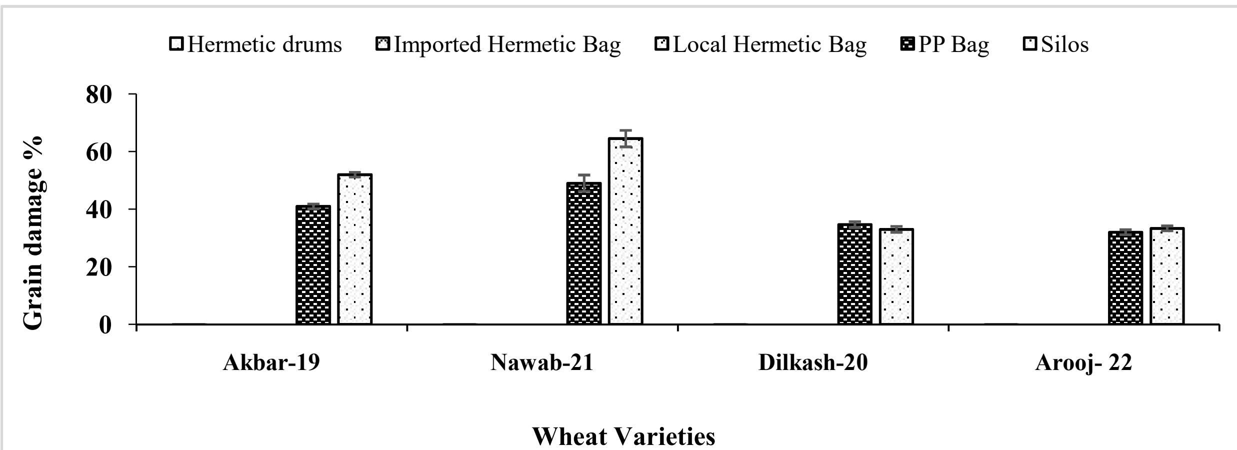


Figure 17 Grain damage (%) at Multan

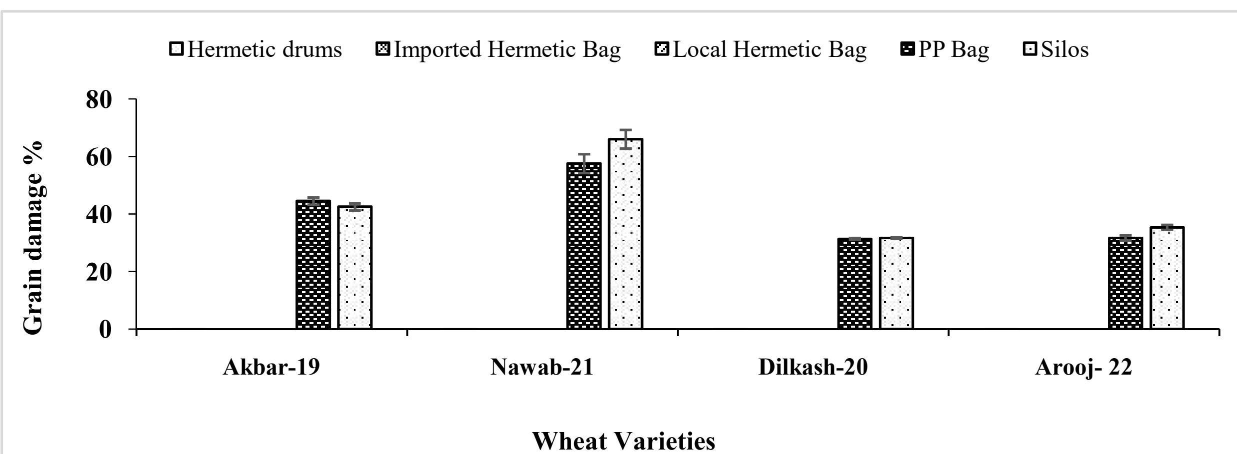


Figure 18 Grain damage (%) at Khanewal location-1

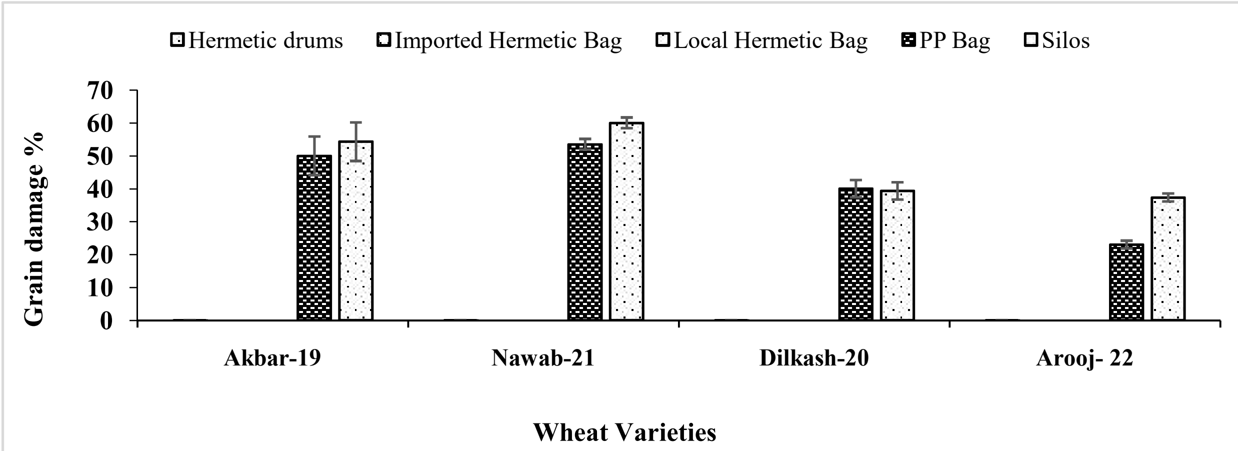


Figure 19 Grain damage (%) at Khanewal location-2

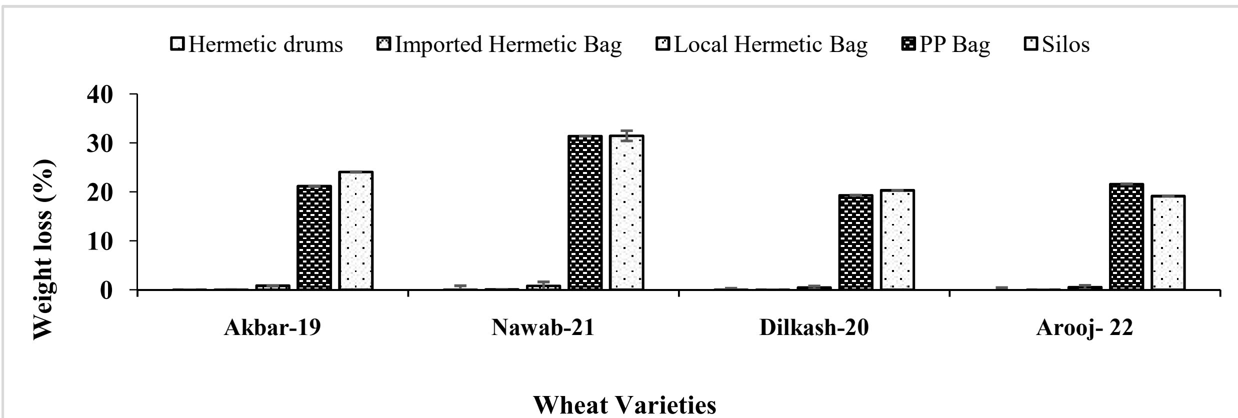


Figure 20 Weight loss (%) at Jalalpur Pirwala

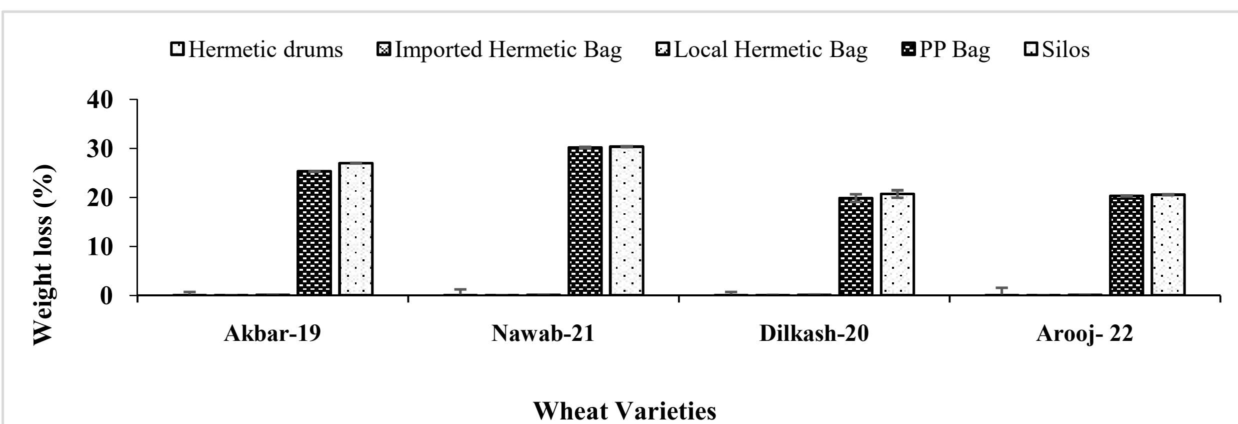


Figure 21 Weight loss (%) at Multan

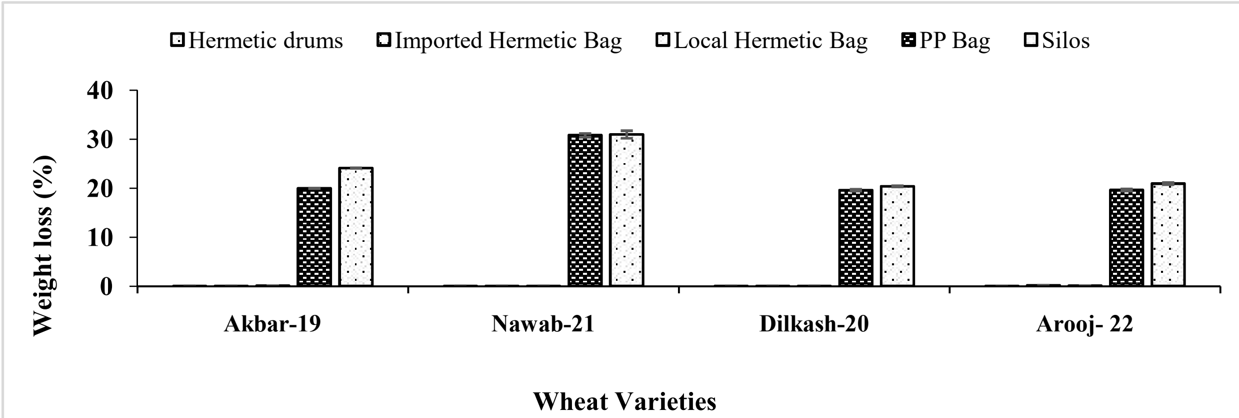


Figure 22 Weight loss (%) at Khanewal location-1

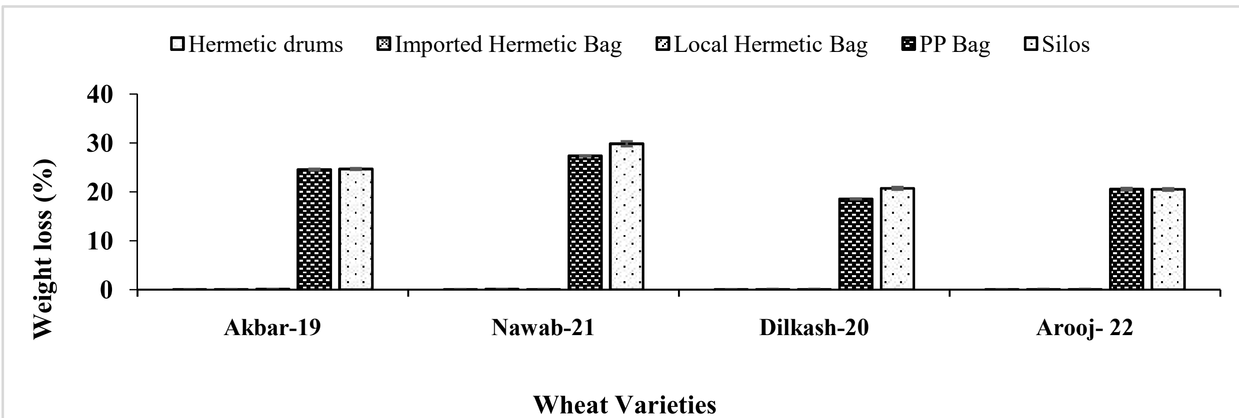


Figure 23 Weight loss (%) at Khanewal location-2

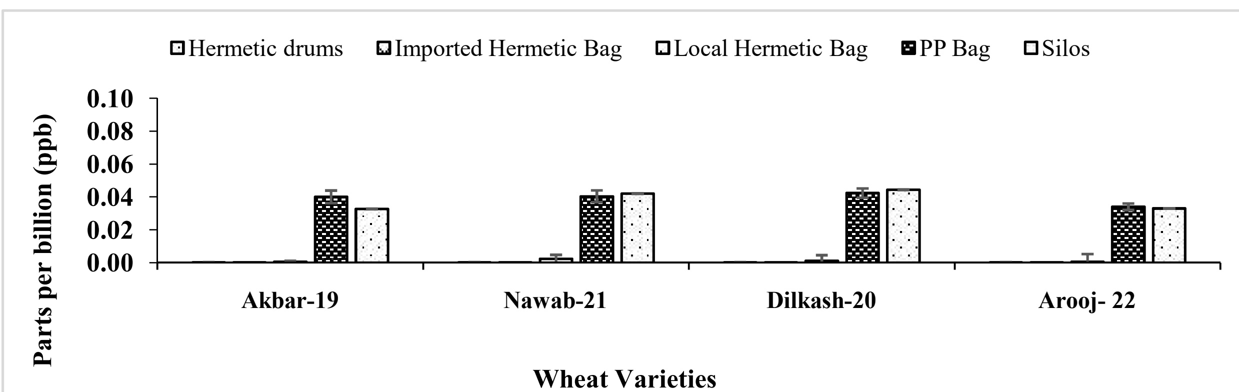


Figure 24 Aflatoxins contamination at Jalalpur Pirwala

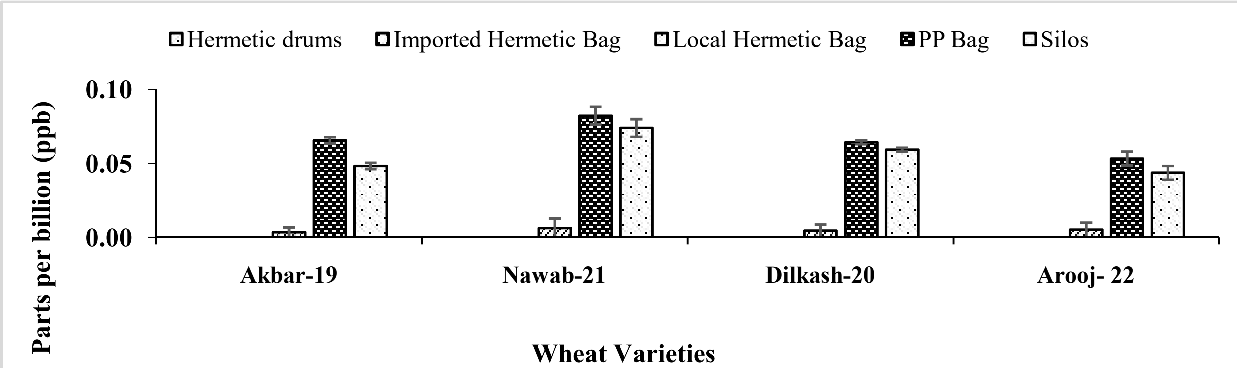


Figure 25 Aflatoxins contamination at Multan

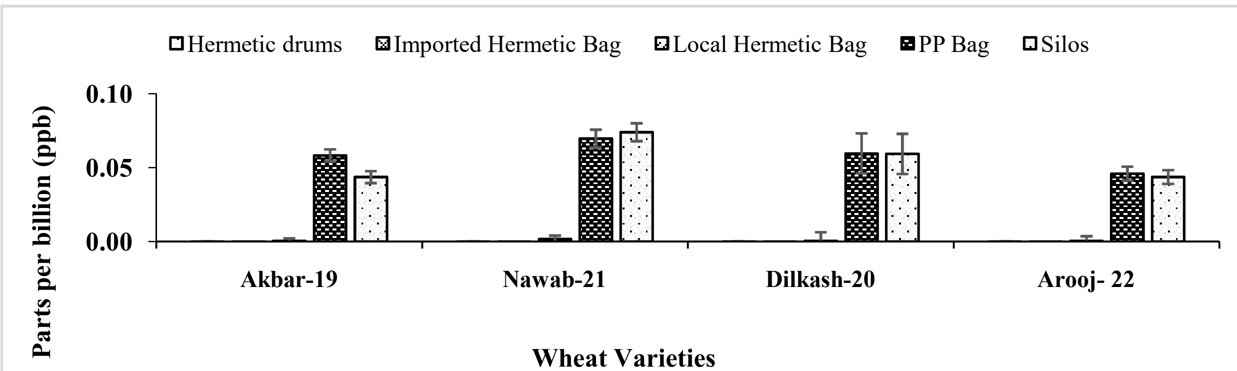


Figure 26 Aflatoxins contamination at Khanewal location-1

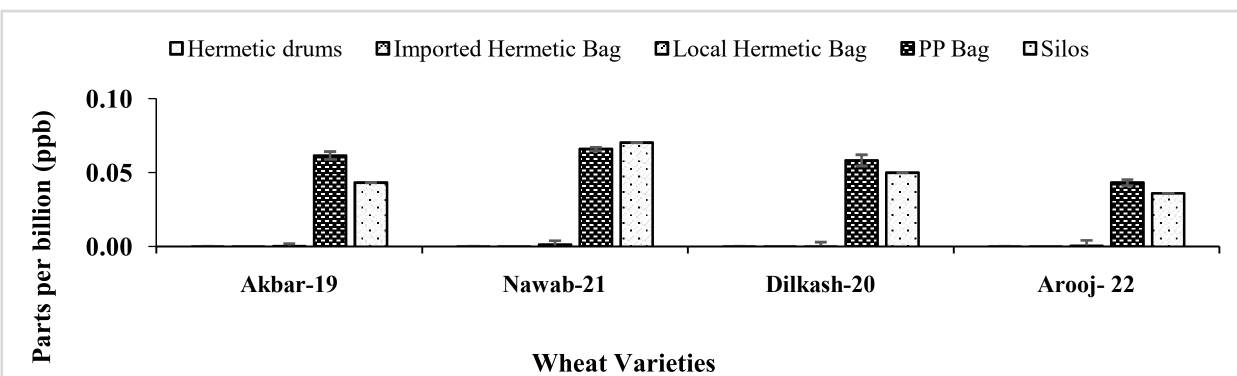


Figure 27 Aflatoxins contamination at Khanewal location-2

7. Economic analysis

The economic analysis of different storage structures showed that hermetic bags were beneficial as well as efficient to reduce seed storage losses with ROI 14.3% for imported hermetic and 17.0% for local hermetic bags. Highest cost benefit ratio was recoded local hermetic bags (1.14) followed by imported hermetic bags (1.06).

Table 1 Return on investment (ROI)

	Imported Hermetic	**Local Hermetic**	**PP Bag**	**Metal Silo**	**Hermetic Drum**
Quantity of seed stored (kg)	50	50	50	50	50
Cost of seed (Rs.)	5250	5250	5250	5250	5250
Life of storage structures (Years)	3	2	1	15	11
Annual storage cost (Rs.)	217	125	50	100	209
Annual total cost	5467	5375	5300	5350	5459
Losses (kg)	0.000	0.105	11.560	12.045	0.055
Sale price per kg	126	126	97.5	97.5	126.0
Revenue (value after storage)	6300	6287	3748	3701	6293
Annual Profit/ Loss (Rs.)	833	912	-1552	-1649	834
ROI (%)	15.2	17.0	-29.3	-30.8	15.3

- Local hermetic bags have the highest 17.0% ROI making it more profitable.
- Imported hermetic bags and hermetic drums have ROI 15 % are also profitable and have better shelf life.
- PP bags and Metal silo have negative ROIs -29.3% and -30.8% respectively, despite long shelf life of metal silo.

Table 2 Cost benefit ratio (CBR)

Storage techniques	Variable cost	Fixed cost	Total cost	Revenue (value after storage)	BCR
Imported hermetic bags	217	5250	5467	6300	1.152369
Local hermetic bags	125	5250	5375	6287	1.169674
PP bags	25	5250	5275	3748	0.710521
Metal silo	100	5250	5350	3701	0.691776
Hermetic Drums	209	5250	5459	6293	1.152775

- Local hermetic bags have the highest 1.16 CBR making it more profitable.
- Imported hermetic bags and Hermetic drums have CBR 1.15 also profitable considering its shelf life.
- PP bags and Metal silo have negative CBR 0.70 and 0.54 respectively.

8. Discussion

The primary cause of seed aging during storage is high seed moisture content. As seeds are hygroscopic entities, they can absorb and release moisture in accordance with the relative humidity of the environment to achieve equilibrium (Strelec *et al.,* 2010). So, temperature changes and RH affects its seed moisture percentage and quality. Results of present study indicated a significant variation in seed moisture contents at four sampling intervals (after 3, 6, 9 and 12 months).

Wheat seed moisture contents were initially higher up to (10.5%) in Nawab-21 while storage techniques like PP bags and iron silos allowed the seeds to lose moisture but moisture loss was not significant in hermetic bags (Figure 4-7). With the passage of time (after 3 to 12 months) there was an increase in RH in the month of January, so moisture of seeds also increased stored in metal silos and PP bags but moisture contents in hermetic bags remained low. Similarly, moisture contents of wheat seeds stored in PP bags were also higher in 12 months sampling interval compared to moisture contents of seeds stored in hermetic bags (Figure 7). The initial Seed moisture percentage was 9.2% to 10.5% but with the passage of time it increases up to the highest level 12.4% at Jalalpur, 15.1% at Multan, 13.6% at Khanewal-1 and 13.6% at Khanewal location-2 in Nawab-21 wheat variety that was mostly stored in PP bags and iron silos.

Germination of the stored crop seeds decreased with the passage of time in all storage techniques. Wheat seeds had no difference in germination after the first 3 months in different storage materials. In the first 3 months the seed moisture contents were not too high to affect the seed viability very quickly. Wheat varieties lost germination rapidly in all packaging materials while hermetic bags maintained high germination rate (Figure 8-11). This difference in germination was observed due to moisture difference because seeds tend to equilibrate with the prevailing RH of the storage environment and gain moisture under situations of high RH and vice versa, high RH was the cause of the increased moisture of wheat seeds in PP bags and metal silos (McDonald, 2007). High moisture content seed storage puts seeds in danger of rapidly losing quality and germination (Bewley *et al.,* 2013). Initially the seed germination ranged between 98.3% to 95.0% while decreased up to 53.3% at Jalalpur, 60.0% at Multan, 53.6% at Khanewal-1 and 48.3% at Khanewal location-2 stored in PP bags and iron silos while the minimum germination 81.6% was recorded in hermetic bags.

By regulating both the relative humidity and the temperature of the place of storage environment, the viability of seeds can be preserved in conditioned storage for a long time. The EC of seed varied low in imported and local hermetic bags (26-36 $\mu S\ cm^{-1}g^{-1}$) in (Figure 12-15) while in case of metal silo and PP bags they were (38-69 $\mu S\ cm^{-1}g^{-1}$) at Multan location in wheat variety Nawab-21. For most crop seeds, it may not be economical to maintain such regulated conditions continuously, but given the importance of germplasm and quality seed stock, this expense may be justified. Electrical conductivity of seed leachates which is inversely related to seed vigor, initially between 26.0-37.0 μS cm^{-1} g^{-1} but increases up to 69.2 μS cm^{-1} g^{-1} at Jalalpur, 69.7 μS cm^{-1} g^{-1} at Multan, 64.5 μS cm^{-1} g^{-1} at Khanewal Location-1 and 62.9 at Khanewal location-2 in the iron silos and PP bags while minimum changes happened in imported hermetic bags as well as local hermetic bags. The highest damaged grain percentage was recorded at location-1 Khanewal 66.0%, 64.5% at Multan, 60.0% at Khanewal location-2 and 54.5% at Jalalpur location in PP bags and iron silos. Hermetic bags had very minor losses which are non-significant but in case of local hermetic bags only about 3.5% damage in few replicates were recorded.

Only conditioned storage may safeguard seed viability in tropical climates from harvest to planting (Harrington, 1973). A type of seed storage that is called "controlled atmosphere" or "modified atmosphere" involves storing seeds in an atmosphere with significantly different CO_2 and O_2 concentrations than regular air. The grain damage percentage and weight loss percentage were also high in PP bags and iron silos. The highest weight loss percentage was recorded at Multan 30 %, Jalalpur 31 %, 31% at Khanewal location-1 and 29 % at Khanewal location-2 in iron silos and PP bags. Hermetic bags had very minor losses which are non-significant but in case of local hermetic bags only about 0.8% weight loss were recorded.

Little amount of contamination was also seen in PP bags and iron silos (Figure 24). The moisture level of grain inoculated with A. flavus and harboring insects increased to 26.4% after ten weeks of storage, there were noticeably more insects in the bottom of the woven bags kept at the Arkansas location than in the top or center. High grain moisture is the key driver of storage losses due to storage insects and fungi (Bakhtavar et al., 2019b). In conclusion, our findings demonstrate that many of the environmental factors that cause grain to spoil are lessened when hermetic storage is used. Rewetting, which can aid in the growth of storage fungus, is prevented by hermetic storage, which acts as a barrier to the exchange with ambient moisture.

9. Results of Nutritional Quality

9.1 Protein (%)

Initial protein percentage in grain of Akbar-19 was 13.2% before storage. Periodic data was recorded for the period of 12 months storage. After 12-month storage at Jalalpur, maximum protein contents in Akbar-19 were 12.93% in imported hermetic bag while minimum protein (11.64%) was recorded from the seed stored in iron silo. At Multan, maximum protein contents (12.97%) were recorded for the seed stored in imported hermetic bag. Minimum protein contents (10.02%) were recorded in iron silo. At Khanewal location I, maximum protein contents (12.57%) were recorded from the seeds stored in imported hermetic bags (Figure 28-31). Minimum protein (10.32%) was recorded from the seeds stored in iron silo. At Khanewal location II, maximum protein contents (12.92%) were recorded from the seeds stored in imported hermetic bag while minimum protein (10.15%) were recorded for the seed stored in iron silo.

Initial protein contents of Nawab-21 were 12.41% before storage. Periodic data of protein % was recorded for the period of 12 months storage. After 12-month storage at Jalalpur, maximum protein contents (12.18%) were recorded from seed stored in imported hermetic bag while minimum protein (10.66%) was recorded from the seed stored in iron silo. At Multan, maximum protein (12.16%) was recorded for the seed stored in imported hermetic bag while minimum protein contents (9.09%) were recorded in iron silo. At Khanewal location I maximum protein (12.13%) was recorded in imported hermetic bag while minimum protein (10.49%) was recorded from the seeds stored in iron silo. At Khanewal location II, maximum protein % was recorded (12.19%) in local hermetic bag while minimum protein contents (9.49%) were in iron silo (Figure 28-31).

Dilkash-20 had the initial protein % up to (12.35%). After 12 months of storage Jalalpur, maximum protein contents were recorded (11.99%) from seed stored in imported hermetic bag while minimum recorded in iron silo (10.91%). Multan location had maximum protein in hermetic bags (12.00%) while minimum (9.21%) recorded in iron silo. Khanewal location I had minimum seed protein in imported hermetic bags (9.32%) while maximum recorded in hermetic bags (11.04%). At Khanewal location II, the highest protein contents were (11.96%) recorded from the seed stored in imported hermetic bags (Figure 28-31) while lowest protein was recorded in iron silo (8.64%).

The initial protein contents of Urooj-22 were (12.37%) at the time of storage. After 12-month storage period at Jalalpur, maximum protein contents (12.15%) were measured in imported hermetic bags while lowest protein (10.86%) was recorded in iron silo. Multan location had the highest protein contents in imported hermetic bag (12.18%) while lowest was recorded in iron silo (9.74%). Khanewal location I had maximum protein contents in imported hermetic bag (12.17%) while minimum protein was recorded in iron silo (9.99%). In case of Khanewal location

II, maximum protein % was recorded in imported hermetic bags (12.17%) while minimum protein % was recorded in iron silo (9.45%) after 12 months storage period (Figure 28-31).

9.2 Fiber (%)

Results of fiber contents (%) varied in different storage structures after 12 months storage. Initially Akbar-19 had (1.44%) fiber content. At Jalalpur, the highest fiber content (1.37%) was recorded for the seed stored in imported hermetic bags while lowest fiber content (1.03%) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest (1.37%) while minimum fiber content (1.17%) was recorded in iron silos. At Khanewal location I, the highest fiber content (1.36%) was recorded for the seed stored in imported hermetic bags while lowest was (1.01%) stored in iron silo. The lowest fiber content (0.99%) recorded in iron silos while highest (1.37%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 32-35).

Fiber content varied in different storage structures after 12 months storage. Initially Nawab-21 variety had 1.43% fiber content. At Jalalpur location after 12 months sampling interval the highest fiber content (1.40%) was in imported hermetic bags while lowest fiber content (1.17%) was stored in iron silo. At Multan, imported hermetic bags had the highest fiber content (1.37%) while minimum fiber content (1.17%) was recorded in iron silos. Khanewal location I had the highest fiber content (1.38%) in imported hermetic bags while lowest was (1.15%) stored in iron silo. The lowest fiber was (1.10%) recorded iron silo while highest (1.37%) in imported hermetic bags at Khanewal location II after 12 months storage (Figure 32-35).

Fiber content varied in different storage structures after 12 months storage. Initially Dilkash had 1.22% fiber content. At Jalalpur location after 12 months sampling interval the highest fiber content 1.17% was measure from seed stored in imported hermetic bags while lowest fiber content (0.91%) was stored in iron silos. At Multan, hermetic bags had the highest fiber content recorded in imported hermetic bags (1.19%) while minimum fiber content (0.99%) was recorded in iron silo. Khanewal location I had the highest fiber content (1.17%) in imported hermetic bags while lowest was (1.01%) stored in iron silo (Figure 32-35). The lowest fiber content (0.91%) recorded in iron silos while highest (1.19%) in imported hermetic bags at Khanewal location II after 4th sampling.

Initially Urooj-22 had 1.15% fiber content. At Jalalpur location after 12 months sampling interval the highest fiber content (1.11%) was in imported hermetic bags while lowest fiber content (0.87%) was stored in iron silos. At Multan, imported hermetic bags had the highest fiber content (1.11%) while minimum fiber content (0.91%) was recorded in iron silo. Khanewal location I, had the highest fiber content (1.12%) in imported hermetic bags while lowest was (0.94%) measure from the seed stored in iron silo. The lowest fiber content (0.89%) recorded in iron silos while highest fiber contents (1.11%) were recorded from seed stored in imported hermetic bags at Khanewal location II after 12 months (Figure 32-35).

9.3 Ash (%)

Results of ash contents (%) varied in different storage structures after 12 months storage. Initially Akbar-19 had 1.96% ash contents. At Jalalpur, the highest ash content (1.94%) was recorded for the seed stored in imported hermetic bags while lowest ash content (1.4%) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest (1.92%) while minimum ash content (1.59%) was recorded in iron silos. At Khanewal location I, the highest ash content (1.9%) was recorded for the seed stored in imported hermetic bags while lowest was (1.58%) stored in iron silo. The lowest ash content (1.63%) recorded in iron silos while highest (1.95%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 36-39).

Initially Nawab-21 variety had 1.96% ash contents. After 12 months storage at Jalalpur, the highest ash content (1.66%) was measured from seed stored in imported hermetic bags while lowest ash content (1.22%) was stored in iron silo. At Multan, imported hermetic bags had the highest ash content (1.92%) while minimum ash content (1.21%) was recorded in iron silos. Khanewal location I, had the highest ash content (1.67%) in imported hermetic bags while lowest was (1.36%) stored in iron silo. The lowest ash content (1.28%) recorded in iron silo while highest (1.72%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 36-39).

Ash content varied in different storage structures after 12 months storage. Initially Dilkash-20 had (1.48%) ash content. At Jalalpur location after 12 months sampling interval the highest ash content (1.43%) was in imported hermetic bags while lowest ash content (0.99%) was stored in iron silos. At Multan, imported hermetic bags had the highest ash content (1.42%) while minimum ash content (0.98%) was recorded in iron silo. At Khanewal location I, the highest ash content (1.43%) was measured in imported hermetic bags while lowest (1.43%) was measured from seed stored in iron silo (Figure 36-39). The lowest ash content (1.18%) recorded in iron silos while highest (1.47%) in imported hermetic bags at Khanewal location II after 4th sampling.

Initially Urooj-22 variety had 1.17% ash content. At Jalalpur location after 12 months sampling interval the highest ash content (1.14%) was in imported hermetic bags while lowest ash content (0.72%) was stored in iron silos. At Multan, imported hermetic bags had the highest ash content (1.13%) while minimum ash content (0.84%) was recorded in iron silo. Khanewal location I, had the highest ash content (1.12%) in imported hermetic bags while lowest was (0.73%) stored in iron silo (Figure 36-39). The lowest ash content (0.74%) recorded in iron silos while highest (1.16%) in imported hermetic bags at Khanewal location II after 4th sampling.

9.4 Fat (%)

Results of fat (%) varied in different storage structures after 12 months storage. Initially Akbar-19 had 1.84% fat content. At Jalalpur, the highest fat content (1.69%) was recorded for the seed stored in imported hermetic bags while lowest fat content (1.43%) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest fat content (1.69%) while minimum fat content (1.42%) was recorded in iron silos. At Khanewal location I, the highest fat content (1.69%) was recorded for the seed stored in imported hermetic bags while lowest was (1.63%) stored in iron silo (Figure 40-43). The lowest fat contents (1.45%) were recorded from seed stored iron silos while highest (1.60%) in imported hermetic bags at Khanewal location II after 4^{th} sampling.

Fat content varied in different storage structures after 12 months storage. Initially Nawab-21 had (1.8%) fat content. At Jalalpur location after 12 months sampling interval the highest fat content (1.66%) was in imported hermetic bags while lowest fat content (1.39%) was stored in iron silo. At Multan, imported hermetic bags had the highest fat content (1.66%) while minimum fat content (1.31%) was recorded in iron silos. Khanewal location I, had the highest fat content (1.66%) in imported hermetic bags while lowest was (1.59%) stored in iron silo. The lowest fat content (1.43%) recorded in iron silo while highest (1.57%) in imported hermetic bags at Khanewal location II after 4^{th} sampling (Figure 40-43).

Fat content varied in different storage structures after 12 months storage. Initially Dilkash-20 had (1.76%) fat content. At Jalalpur location after 12 months sampling interval the highest fat content (1.64%) was in imported hermetic bags while lowest fat content (1.31%) was stored in iron silos. At Multan, imported hermetic bags had the highest fat content (1.64%) while minimum fat content (1.30%) was recorded in iron silo. At Khanewal location I, had the highest fat contents (1.64%) were in imported hermetic bags while lowest was (1.55%) stored in iron silo (Figure 40-43). The lowest fat content (1.30%) recorded in iron silos while highest (1.64%) in imported hermetic bags at Khanewal location II after 4^{th} sampling.

Initially Urooj-22 had (1.72%) fat content. At Jalalpur location after 12 months sampling interval the highest fat content (1.73%) was in imported hermetic bags while lowest fat content (1.32%) was stored in iron silos. At Multan, imported hermetic bags had the highest fat content (1.73%) while minimum fat content (1.37%) was recorded in iron silo. Khanewal location I, had the highest fat content (1.73%) in imported hermetic bags while lowest was (1.50%) stored in iron silo. The lowest fat content (1.31%) recorded in iron silos while highest (1.66%) in imported hermetic bags at Khanewal location II after 4^{th} sampling (Figure 40-43).

9.5 Thousand Kernel Weight (TKW)

Results of thousand kernel weight varied in different storage structures after 12 months storage. Initially Akbar-19 had (44.9 g) thousand kernel weight. At Jalalpur, the highest thousand kernel weight (44.38 g) was recorded for the seed stored in local hermetic bags while lowest thousand kernel weight (34.67 g) was recorded for the seed stored in iron silo. At Multan, local hermetic bags had the highest thousand kernel weight (44.62) while minimum thousand kernel weight (35.04) was recorded in iron silos. At Khanewal location I, the highest thousand kernel weight (44.38 g) was recorded for the seed stored in local hermetic bags while lowest was (31.37 g) stored in iron silo. The lowest thousand kernel weight (32.72 g) recorded in iron silos while highest (44.28) in local hermetic bags at Khanewal location II after 4^{th} sampling (Figure 44-47).

Thousand kernel weight varied in different storage structures after 12 months storage. Initially Nawab-21 had 44.74 g thousand kernel weight. At Jalalpur location after 12 months sampling interval the highest thousand kernel weight (44.54 g) was in imported hermetic bags while lowest thousand kernel weight (35.20 g) was stored in iron silo. At Multan, local hermetic bags had the highest thousand kernel weight (43.86) while minimum thousand kernel weight (35.04 g) was recorded in iron silos. Khanewal location I, had the highest thousand kernel weight (44.14 g) in imported hermetic bags while lowest was (33.42 g) stored in iron silo (Figure 44-47). The lowest thousand kernel weight (33.72 g) recorded in iron silo while highest (44.09 g) in local hermetic bags at Khanewal location II after 4^{th} sampling.

Thousand kernel weight varied in different storage structures after 12 months storage. Initially Dilkash-20 had 43.35 g thousand kernel weight. At Jalalpur location after 12 months sampling interval the highest thousand kernel weight (43.06 g) was in local hermetic bags while lowest thousand kernel weight (30.06 g) was stored in iron silos. At Multan, imported hermetic bags had the highest thousand kernel weight (43.22 g) while minimum thousand kernel weight (32.75 g) was recorded in iron silo. Khanewal location I, had the highest thousand kernel weight (42.92 g) in imported hermetic bags while lowest was (30.69 g) stored in iron silo (Figure 44-47). The lowest thousand kernel weight (30.06 g) recorded in iron silos while highest (43.16) in imported hermetic bags at Khanewal location II after 4^{th} sampling.

Initially Urooj-22 had initial thousand kernel weight of 42.3 g. At Jalalpur location after 12 months sampling interval the highest thousand kernel weight (42.25 g) was in local hermetic bags while lowest thousand kernel weight (34.14 g) was stored in iron silos. At Multan, local hermetic bags had the highest thousand kernel weight (42.26 g) while minimum thousand kernel weight (33.13) was recorded in iron silo. Khanewal location I, had the highest thousand kernel weight (42.15 g) in local hermetic bags while lowest was (31.94 g) stored in iron silo. The lowest thousand kernel weight (30.94 g) recorded in iron silos while highest (42.16 g) in imported hermetic bags at Khanewal location II after 4^{th} sampling (Figure 44-47).

9.6 Test Weight (kg/hl)

Results of test weight varied in different storage structures after 12 months storage. Initially Akbar-19 had 76.9 g test weight. At Jalalpur, the highest test weight (76.85 g) was recorded for the seed stored in imported hermetic bags while lowest test weight (71.92 g) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest test weight (76.08 g) while minimum test weight (71.14 g) was recorded in iron silos. At Khanewal location I, the highest test weight (76.87 g) was recorded for the seed stored in imported hermetic bags while lowest was (71.94 g) stored in iron silo. The lowest test weight (71.92 g) recorded in iron silos while highest (76.86 g) in imported hermetic bags at Khanewal location II after 4^{th} sampling (Figure 48-51).

Test weight varied in different storage structures after 12 months storage. Initially Nawab-21 had 73 g test weight. At Jalalpur location after 12 months sampling interval the highest test weight (72.95 g) was in imported hermetic bags while lowest test weight (68.02 g) was stored in iron silo. At Multan, imported hermetic bags had the highest test weight (71.82 g) while minimum test weight (66.69 g) was recorded in iron silo. Khanewal location I had the highest test weight (72.97 g) in imported hermetic bags while lowest was (68.04 g) stored in iron silo (Figure 48-51). The lowest test weight (68.83 g) recorded in iron silo while highest (72.96 g) in imported hermetic bags at Khanewal location II after 4^{th} sampling.

Test weight varied in different storage structures after 12 months storage. Initially Dilkash-20 had 72.4 g test weight. At Jalalpur location after 12 months sampling interval the highest test weight (72.35 g) was in imported hermetic bags while lowest test weight (67.3 g) was stored in iron silos. At Multan, imported hermetic bags had the highest test weight (72 g) while minimum test weight (66.53 g) was recorded in iron silo. Khanewal location I, had the highest test weight (72.37 g) in imported hermetic bags while lowest was (67.32 g) stored in iron silo (Figure 48-51). The lowest test weight (67.29 g) recorded in iron silos while highest (72.36 g) in imported hermetic bags at Khanewal location II after 4^{th} sampling.

Initially Urooj-22 had 74 g test weight. At Jalalpur location after 12 months sampling interval the highest test weight (73.95 g) was in imported hermetic bags while lowest test weight (68.99 g) was stored in iron silos. At Multan, imported hermetic bags had the highest test weight (72.92 g) while minimum test weight (67.76 g) was recorded in iron silo. Khanewal location I, had the highest test weight (73.97 g) in imported hermetic bags while lowest was (69.01 g) stored in iron silo. The lowest test weight (67.8 g) recorded in iron silos while highest (73.96 g) in imported hermetic bags at Khanewal location II after 4^{th} sampling (Figure 48-51).

9.7 Wet Gluten (%)

Results of wet gluten varied in different storage structures after 12 months storage. Initially Akbar-19 had 24.75% wet gluten content. At Jalalpur, the highest wet gluten (24.68%) was recorded for the seed stored in imported hermetic bags while lowest wet gluten (22.35%) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest wet gluten 23.19% while minimum wet gluten 22.56% was recorded in iron silos. At Khanewal location I, the highest wet gluten (25.17%) was recorded for the seed stored in imported hermetic bags while lowest was (24.07%) stored in iron silo. The lowest wet gluten (24.06%) recorded in iron silos while highest (24.68%) in PP bags at Khanewal location II after 4th sampling (Figure 52-55).

Wet gluten varied in different storage structures after 12 months storage. Initially Nawab-21 had 24.73% wet gluten. At Jalalpur location after 12 months sampling interval the highest wet gluten (24.71%) was in imported hermetic bags while lowest wet gluten (22.07%) was stored in iron silo. At Multan, imported hermetic bags had the highest wet gluten (24.72%) while minimum wet gluten (22.78%) was recorded in iron silos. Khanewal location I, had the highest wet gluten (25.33%) in imported hermetic bags while lowest was (24.25%) stored in iron silo (Figure 52-55). The lowest wet gluten (24.23%) recorded in iron silo while highest (24.68%) in imported hermetic bags at Khanewal location II after 4th sampling.

Wet gluten varied in different storage structures after 12 months storage. Initially Dilkash-20 had (24.71%) wet gluten. At Jalalpur location after 12 months sampling interval the highest wet gluten (24.61%) was in imported hermetic bags while lowest wet gluten (22.13%) was stored in PP bags. At Multan, imported hermetic bags had the highest wet gluten (24.72%) while minimum wet gluten (22.12%) was recorded in iron silo (Figure 52-55). Khanewal location I, had the highest wet gluten (24.85%) in imported hermetic bags while lowest was (23.77%) stored in iron silo. The lowest wet gluten (23.71%) recorded in iron silos while highest (24.68%) in imported hermetic bags at Khanewal location II after 4th sampling.

Initially Urooj-22 had (24.68%) wet gluten. At Jalalpur location after 12 months sampling interval the highest wet gluten (24.58%) was in imported hermetic bags while lowest wet gluten (22.01%) was stored in iron silos. At Multan, imported hermetic bags had the highest wet gluten (24.63%) while minimum wet gluten (22.09%) was recorded in iron silo. Khanewal location I, had the highest wet gluten (23.16%) in imported hermetic bags while lowest was (21.98%) stored in iron silo. The lowest wet gluten (21.96%) recorded in iron silos while highest (23.14%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 52-55).

9.8 Dry Gluten (%)

Results of dry gluten varied in different storage structures after 12 months storage. Initially Akbar-19 had (9.47) dry gluten content. At Jalalpur, the highest dry gluten (9.42%) was recorded for the seed stored in imported hermetic bags while lowest dry gluten (6.94%) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest dry gluten (9.42%) while minimum dry gluten (8.03%) was recorded in iron silos (Figure 56-59). At Khanewal location I, the highest dry gluten (9.46%) was recorded for the seed stored in imported hermetic bags while lowest was (7.67%) stored in iron silo. The lowest dry gluten (7.73%) recorded in iron silos while highest (9.42%) in imported hermetic bags at Khanewal location II after 4th sampling.

Dry gluten varied in different storage structures after 12 months storage. Initially Nawab-21 had (9.47%) dry gluten. At Jalalpur location after 12 months sampling interval the highest dry gluten (9.41%) was in imported hermetic bags while lowest dry gluten (7.16%) was stored in iron silo. At Multan, local hermetic bags had the highest dry gluten (9.46%) while minimum dry gluten (8.8%) was recorded in PP bags. Khanewal location I, had the highest dry gluten (9.45%) in imported hermetic bags while lowest was (7.87%) stored in iron silo. The lowest dry gluten (8.02%) recorded in iron silo while highest (9.48%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 56-59).

Dry gluten varied in different storage structures after 12 months storage. Initially Dilkash-20 had (9.32%) dry gluten. At Jalalpur location after 12 months sampling interval the highest dry gluten (9.24%) was in imported hermetic bags while lowest dry gluten (7.2%) was stored in iron silo. At Multan, imported hermetic bags had the highest dry gluten (9.34%) while minimum dry gluten (7.97%) was recorded in iron silo (Figure 56-59). Khanewal location I, had the highest dry gluten (9.29%) in imported hermetic bags while lowest was (7.27%) stored in iron silo. The lowest dry gluten (7.42%) recorded in iron silos while highest (9.34%) in imported hermetic bags at Khanewal location II after 4th sampling.

Initially Urooj-22 had (8.98%) dry gluten. At Jalalpur location after 12 months sampling interval the highest dry gluten (8.9%) was in imported hermetic bags while lowest dry gluten (7.01%) was stored in iron silos. At Multan, imported hermetic bags had the highest dry gluten (8.96%) while minimum dry gluten (7.34%) was recorded in iron silo. Khanewal location I, had the highest dry gluten (8.94%) in imported hermetic bags while lowest was (7.15%) stored in iron silo. The lowest dry gluten (7.74%) recorded in iron silos while highest (8.96%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 56-59).

9.9 Iron (Fe)

Results of iron content varied in different storage structures after 12 months storage. Initially Akbar-19 had (19.86) iron content. At Jalalpur, the highest iron content (19.85%) was recorded for the seed stored in imported hermetic bags while lowest iron content (15.51%) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest iron content (19.82%) while minimum iron content (16.35%) was recorded in iron silos. At Khanewal location I, the highest iron content (19.84%) was recorded for the seed stored in imported hermetic bags while lowest was (15.81%) stored in iron silo. The lowest iron content (15.63%) recorded in iron silos while highest (19.84%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 60-63).

Iron content varied in different storage structures after 12 months storage. Initially Nawab-21 variety had 25.05% iron content. At Jalalpur location after 12 months sampling interval, the highest iron contents (25.01%) were in imported hermetic bags while lowest iron content (20.71%) was stored in iron silo (Figure 60-63). At Multan, local hermetic bags had the highest iron content (25.02%) while minimum iron content (21.79%) was recorded in iron silo. Khanewal location I, had the highest iron content (25.04%) in local hermetic bags while lowest was (21.03%) stored in iron silo. The lowest iron content (20.79%) recorded in iron silo while highest (24.92%) in imported hermetic bags at Khanewal location II after 4th sampling.

Initially Dilkash-20 variety had 26.49% iron content. At Jalalpur location after 12 months sampling interval the highest iron content (26.43%) was in imported hermetic bags while lowest iron content (22.14%) was stored in iron silo. At Multan, imported hermetic bags had the highest iron content (26.45%) while minimum iron content (23.07%) was recorded in iron silo. Khanewal location I, had the highest iron content (26.44%) in imported hermetic bags while lowest was (22.60%) stored in iron silo (Figure 60-63). The lowest iron content (22.20%) recorded in iron silos while highest (26.43%) in imported hermetic bags at Khanewal location II after 4th sampling.

Initially Urooj-22 variety had (17.96%) iron content. At Jalalpur location after 12 months sampling interval the highest iron content (17.94%) was in imported hermetic bags while lowest iron content (13.62%) was stored in iron silos. At Multan, imported hermetic bags had the highest iron content (17.93%) while minimum iron content (14.49%) was recorded in iron silo. Khanewal location I had the highest iron content (17.94%) in n the seed stored in imported hermetic bags while lowest was (12.85%) stored in iron silo. The lowest iron content (13.60%) recorded in iron silos while highest (17.73%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 60-63).

9.10 Zinc (ppm)

Results of zinc content varied in different storage structures after 12 months storage. Initially Akbar-19 had (33.8) zinc content. At Jalalpur, the highest zinc content (33.81%) was recorded for the seed stored in imported hermetic bags while lowest zinc content (29.44%) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest zinc content (33.76%) while minimum zinc content (23.62%) was recorded in iron silos. At Khanewal location I, the highest zinc content (33.75%) was recorded for the seed stored in imported hermetic bags while lowest was (29.44%) stored in iron silo (Figure 64-67). The lowest zinc content (23.66%) recorded in iron silos while highest (33.77%) in imported hermetic bags at Khanewal location II after 4th sampling.

Zinc content varied in different storage structures after 12 months storage. Initially Nawab-21 had 41.17% zinc content. At Jalalpur location after 12 months sampling interval the highest zinc content (41.15%) was in imported hermetic bags while lowest zinc content (36.75%) was stored in iron silo. At Multan, imported hermetic bags had the highest zinc content (41.15%) while minimum zinc content (29.40%) was recorded in iron silo. Khanewal location I, had the highest zinc content (41.12%) in imported hermetic bags while lowest was (36.93%) stored in iron silo. The lowest zinc content (34.02%) recorded in iron silo while highest (41.14%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 64-67).

Initially Dilkash-20 had 28.9% zinc content. At Jalalpur location after 12 months sampling interval, the highest zinc contents (28.89%) were measured in local hermetic bags while lowest zinc content (23.76%) was stored in iron silo (Figure 64-67). At Multan, imported hermetic bags had the highest zinc content (28.81%) while minimum zinc content (36.89%) was recorded in iron silo. Khanewal location I, had the highest zinc content (28.87%) in imported hermetic bags while lowest was (24.56%) stored in iron silo. The lowest zinc content (22.73%) recorded in iron silos while highest (28.85%) in imported hermetic bags at Khanewal location II after 4th sampling.

Initially Urooj-22 had 28% zinc contents. At Jalalpur location after 12 months sampling interval, the highest zinc contents (28.02%) were measured from the seed stored in imported hermetic bags while lowest zinc content (23.69%) was stored in iron silos. At Multan, imported hermetic bags had the highest zinc content (28%) while minimum iron content (24.52%) was recorded in iron silo. Khanewal location I had the highest zinc content (27.98%) in imported hermetic bags while lowest was (23.66%) stored in iron silo. The lowest zinc content (20.75%) recorded in iron silos while highest was (27.98%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 64-67).

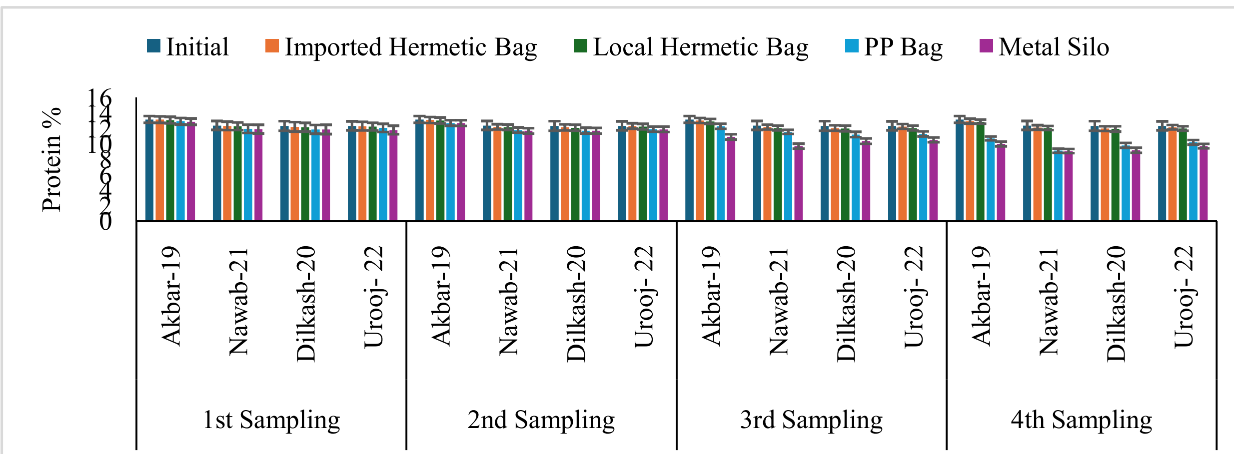


Figure 28 Protein content (%) of wheat varieties stored in different bags/silos at Jalalpur

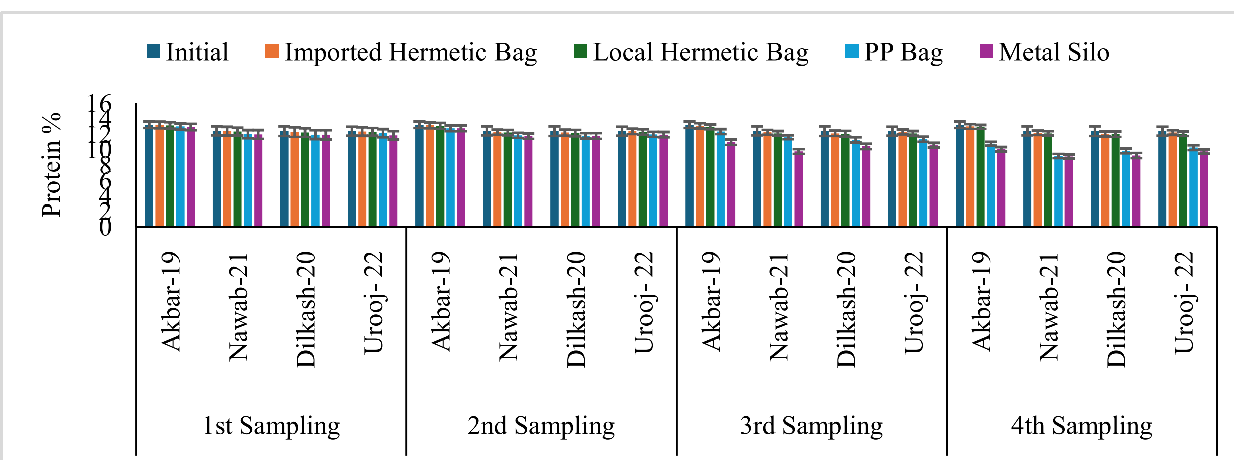


Figure 29 Protein content (%) of wheat varieties stored in different bags/silos at Multan

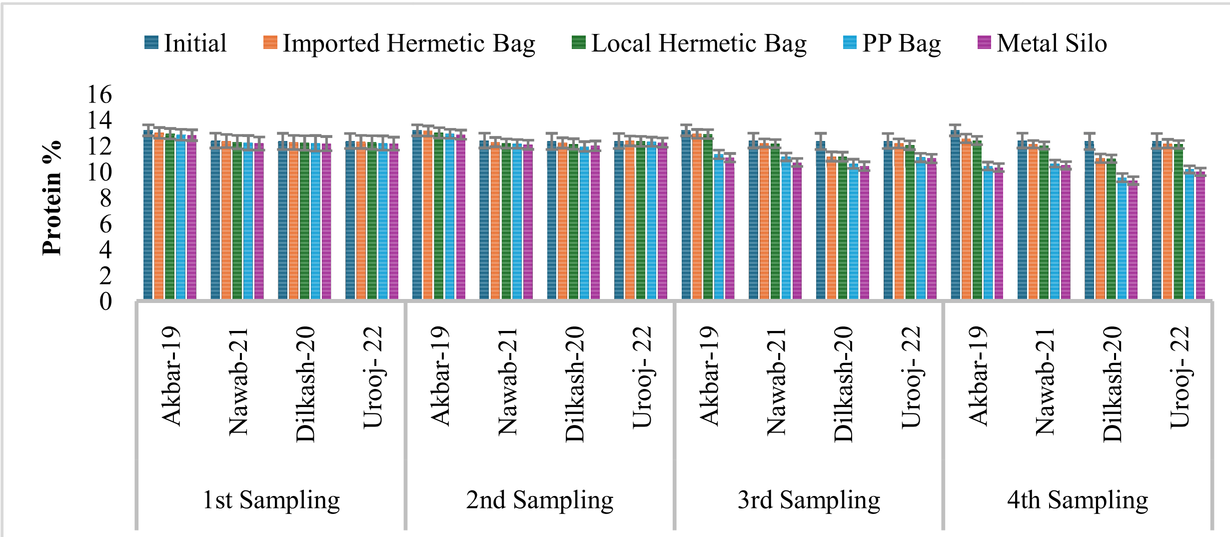


Figure 30 Protein content (%) of wheat varieties stored in different bags/silos at Khanewal I

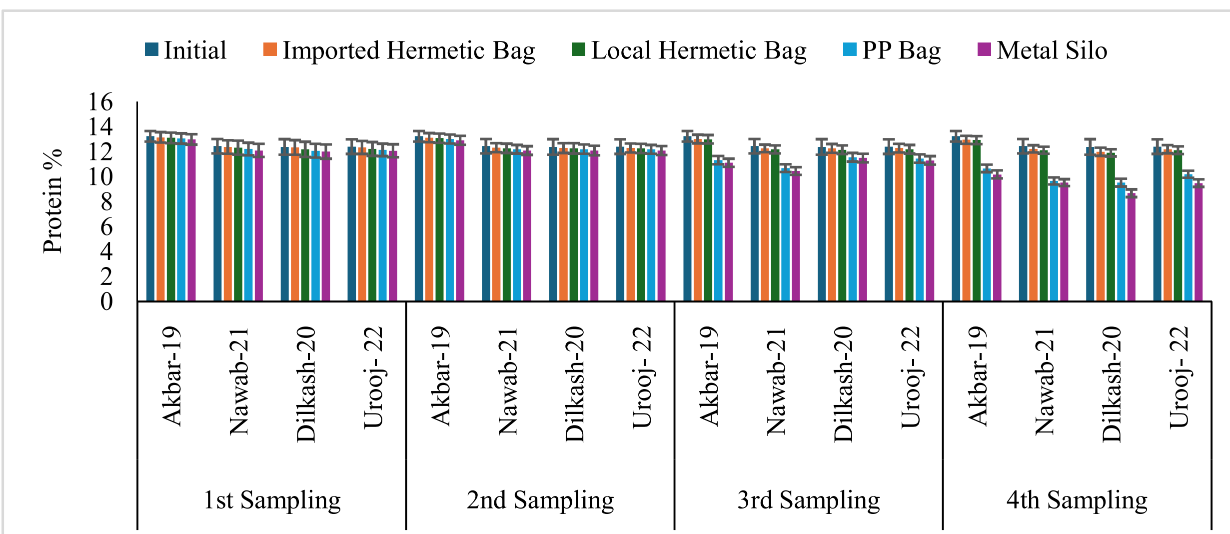


Figure 31 Protein content (%) of wheat varieties stored in different bags/silos at Khanewal II

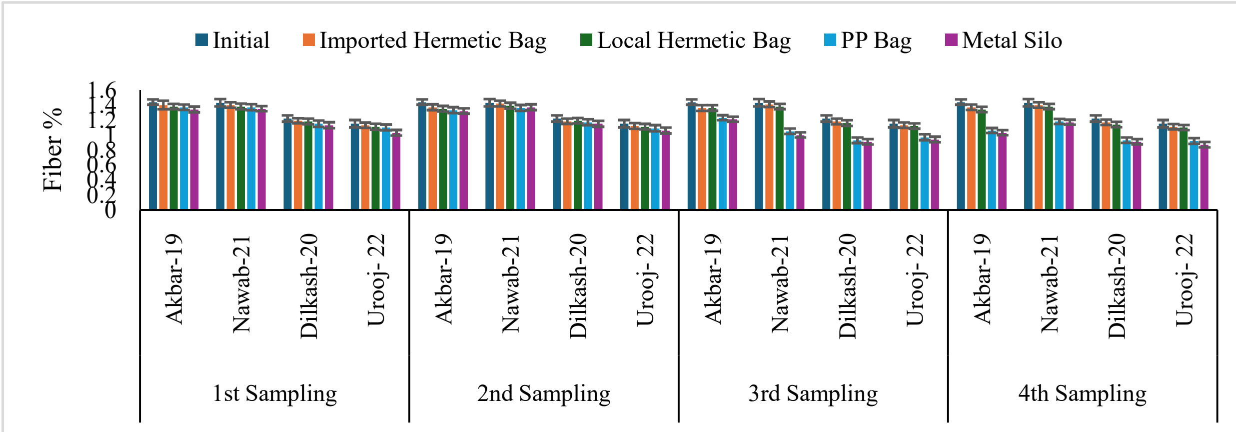


Figure 32 Fiber content (%) of wheat varieties stored in different bags/silos at Jalalpur

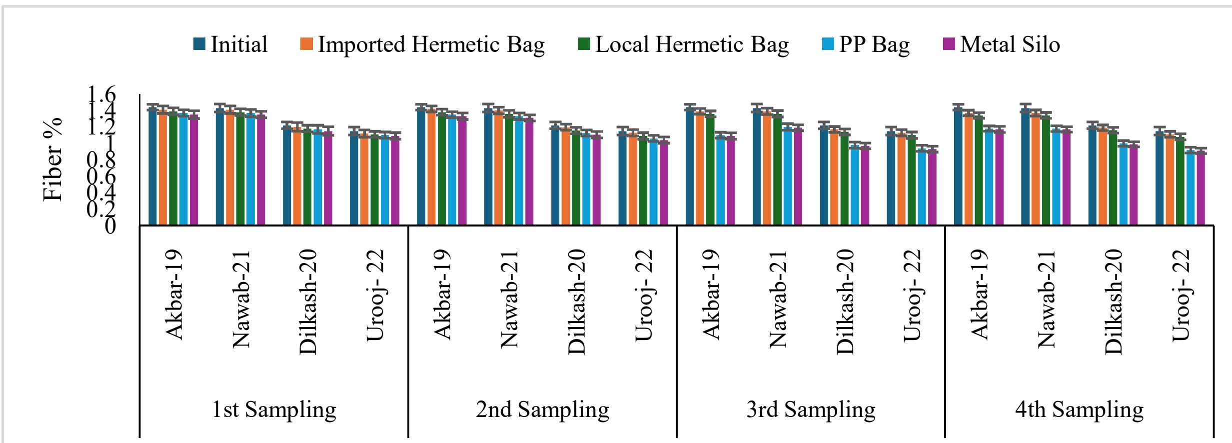


Figure 33 Fiber content (%) of wheat varieties stored in different bags/silos at Multan

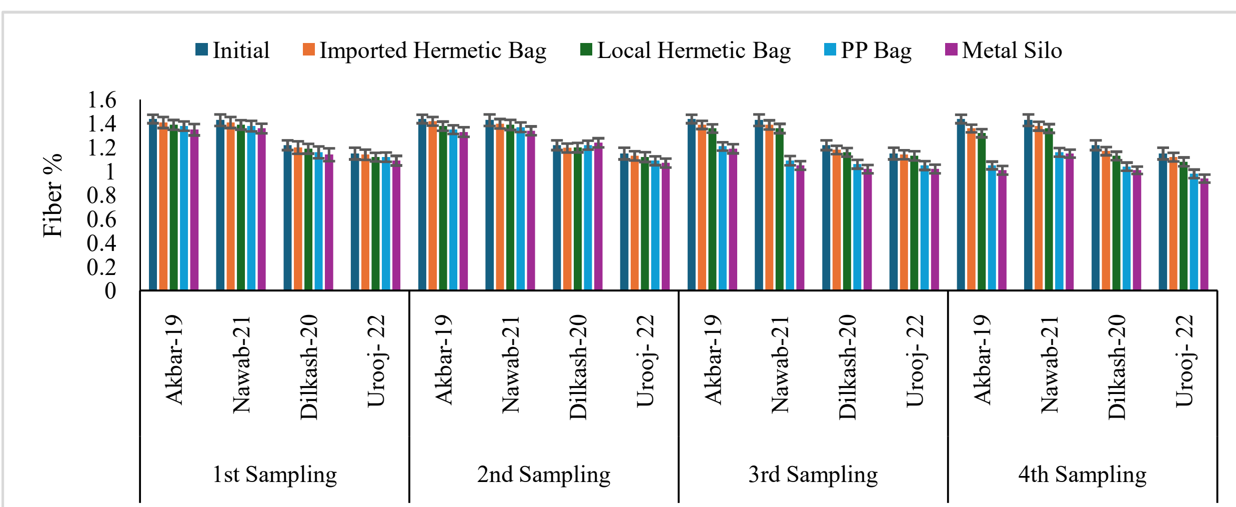


Figure 34 Fiber content (%) of wheat varieties stored in different bags/silos at Khanewal I

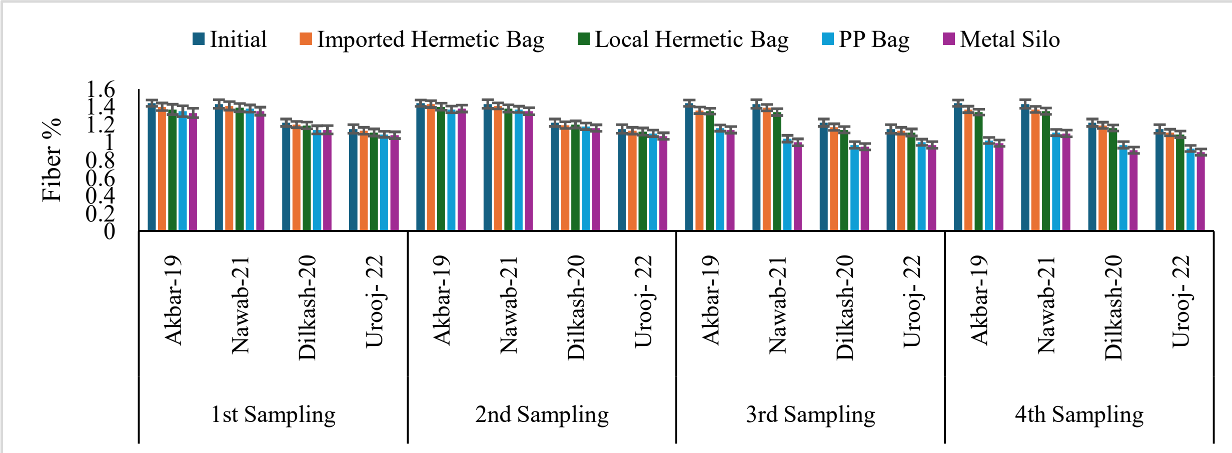


Figure 35 Fiber content (%) of wheat varieties stored in different bags/silos at Khanewal II

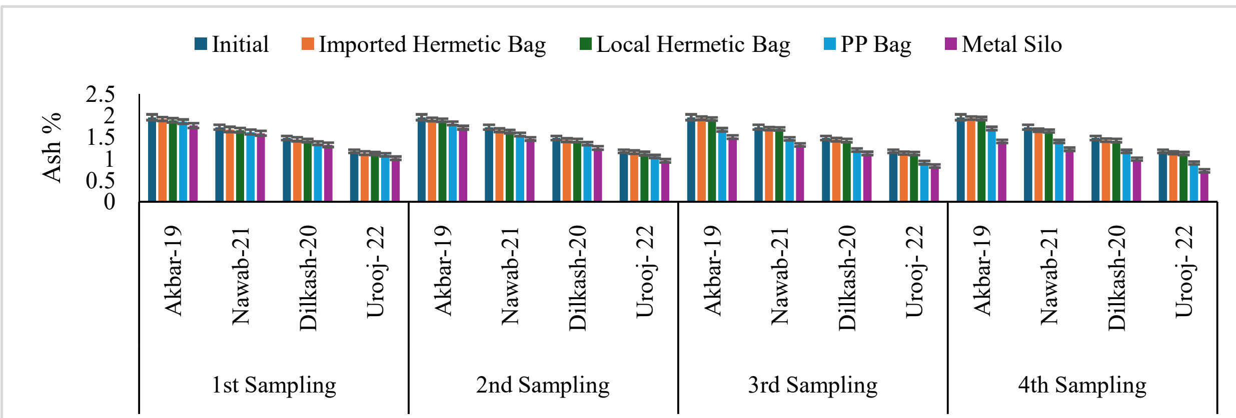


Figure 36 Ash content (%) of wheat varieties stored in different bags/silos at Jalalpur

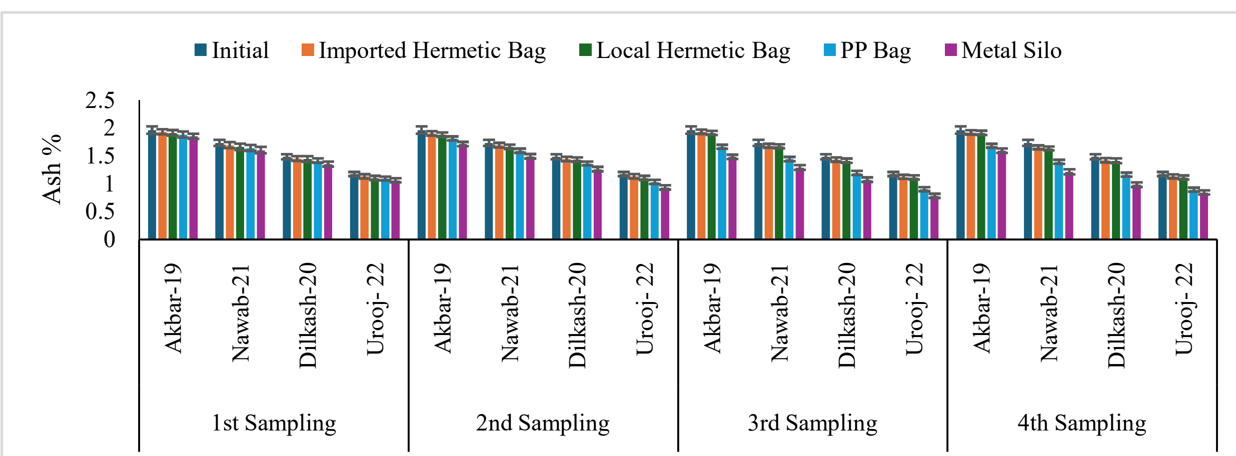


Figure 37 Ash content (%) of wheat varieties stored in different bags/silos at Multan

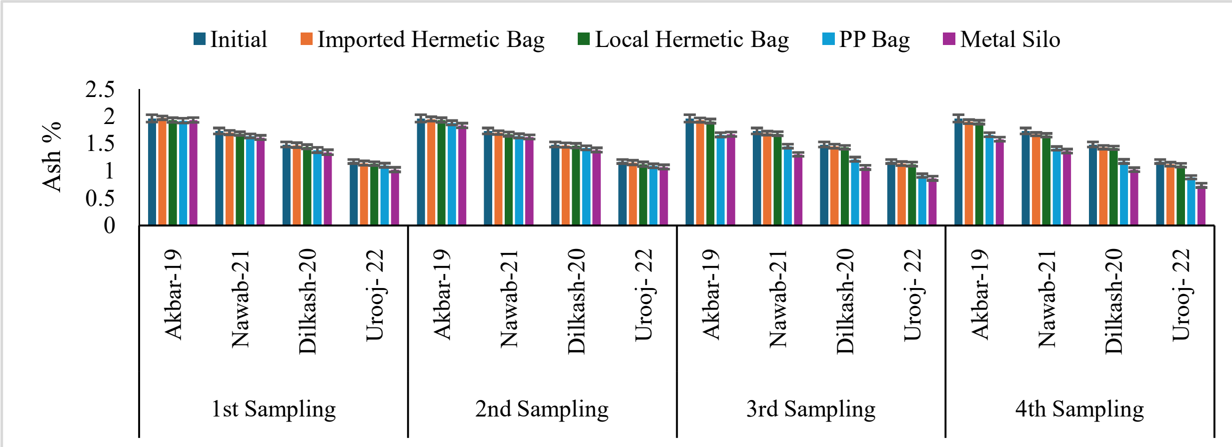


Figure 38 Ash content (%) of wheat varieties stored in different bags/silos at Khanewal I

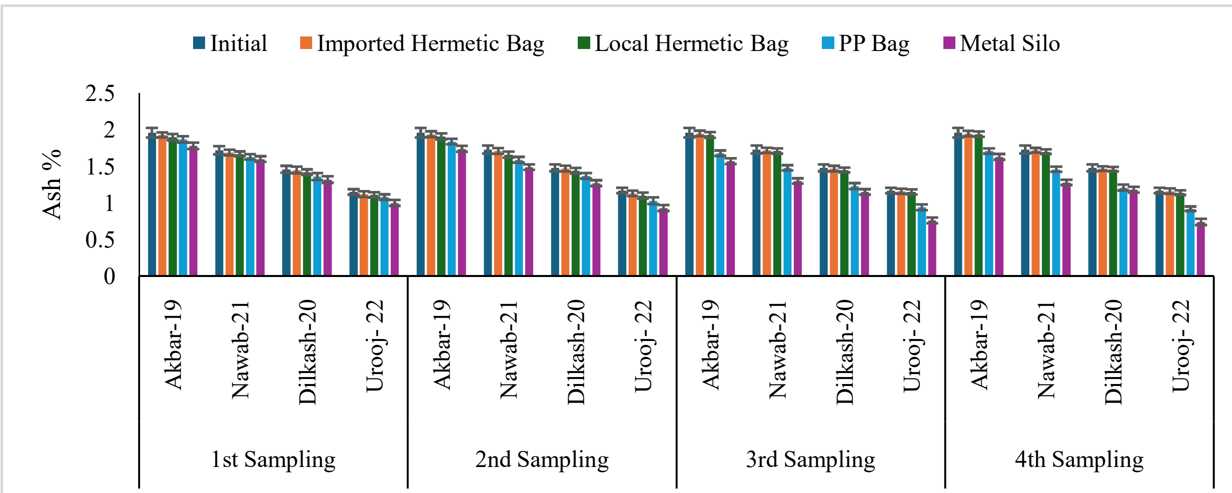


Figure 39 Ash content (%) of wheat varieties stored in different bags/silos at Khanewal II

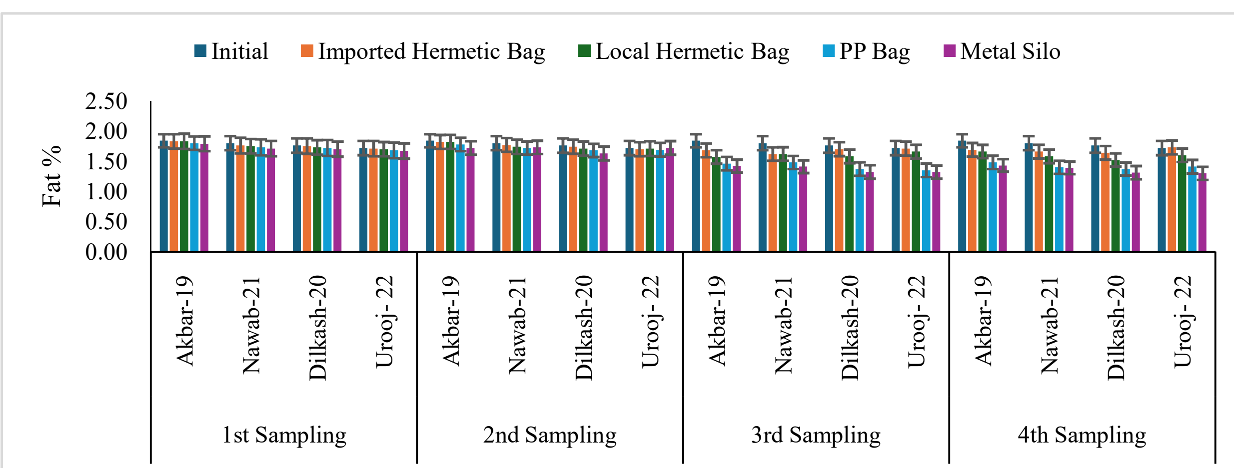


Figure 40 Fat content (%) of wheat varieties stored in different bags/silos at Jalalpur

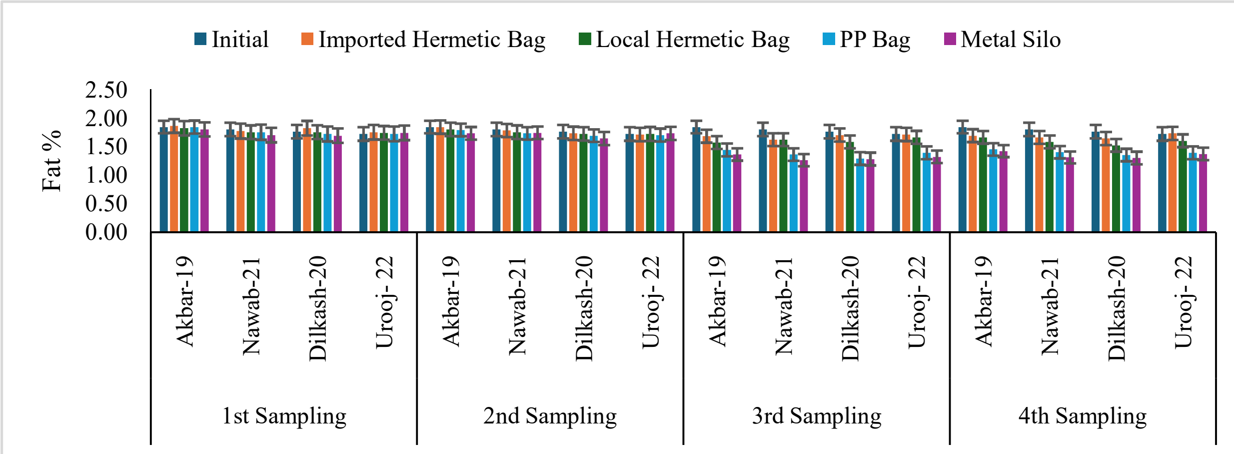


Figure 41 Fat content (%) of wheat varieties stored in different bags/silos at Multan

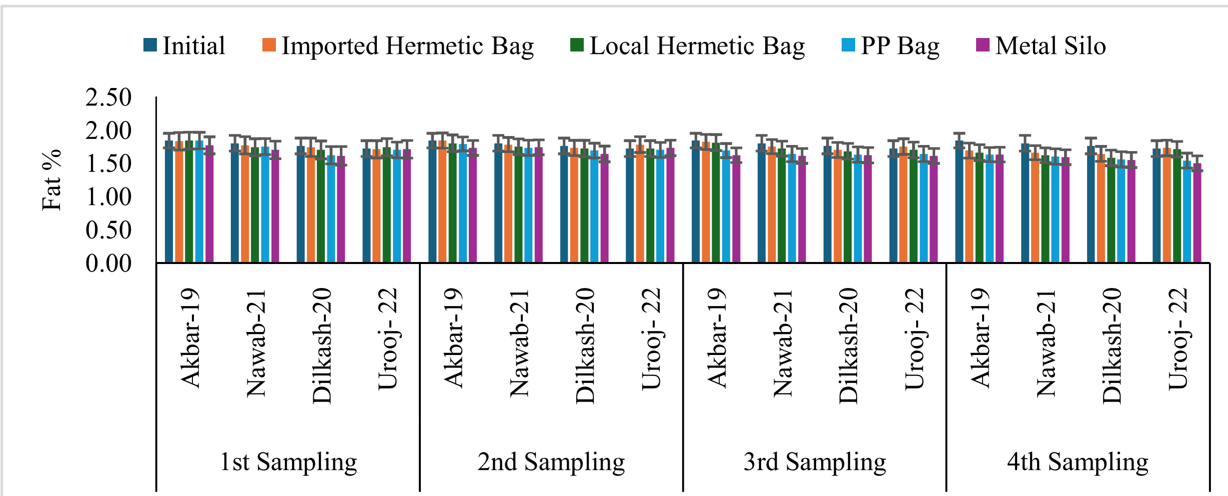


Figure 42 Fat content (%) of wheat varieties stored in different bags/silos at Khanewal I

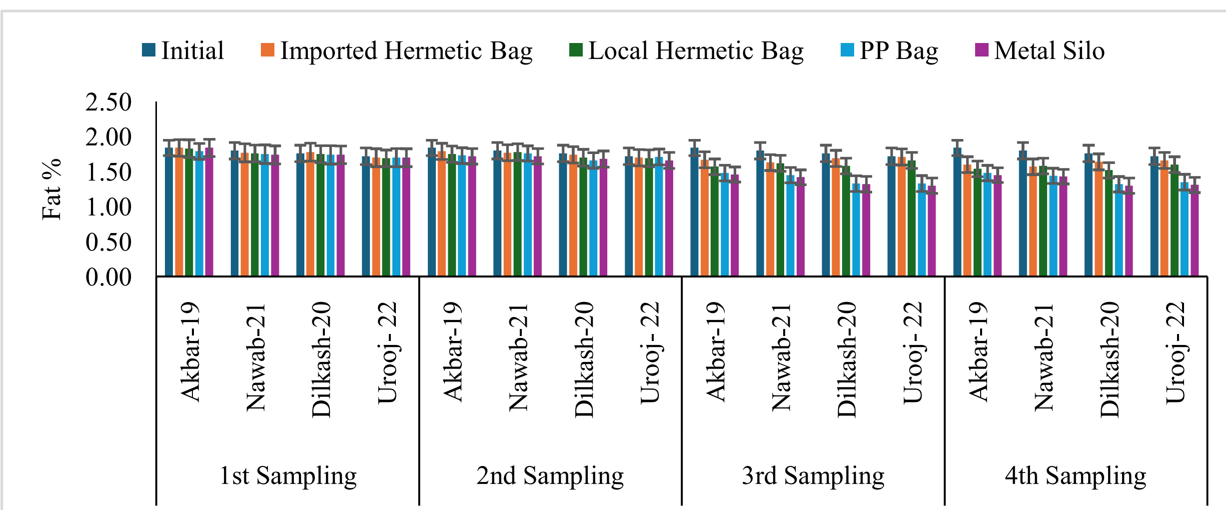


Figure 43 Fat content (%) of wheat varieties stored in different bags/silos at Khanewal II

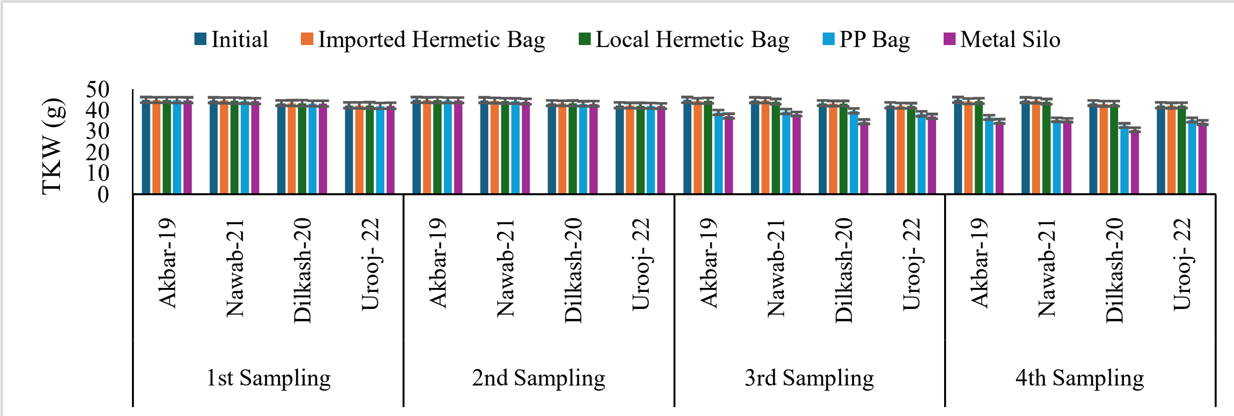


Figure 44 Thousand kernel weight TKW (g) of wheat varieties stored in different bags/silos at Jalalpur

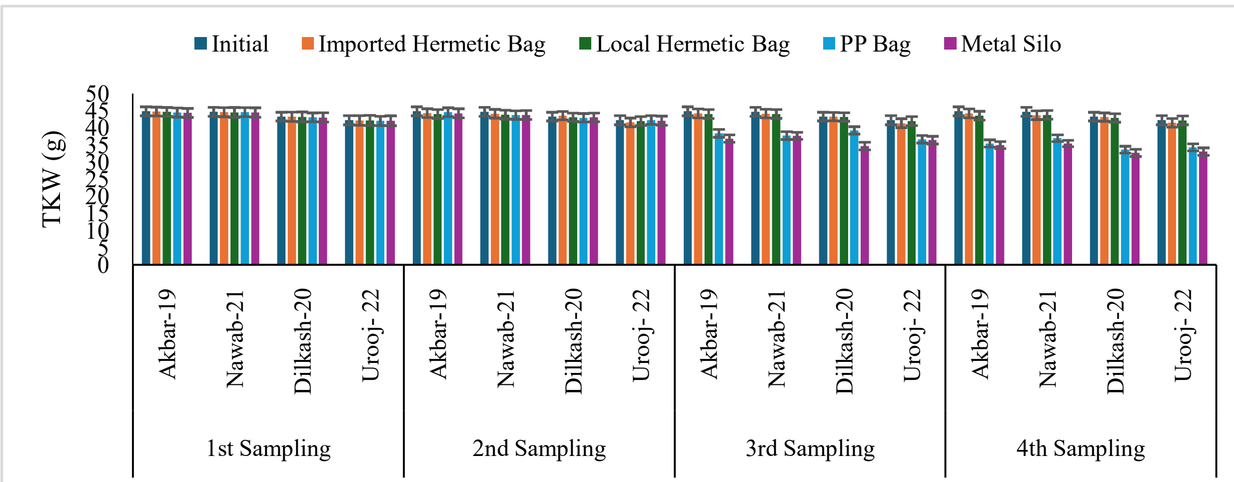


Figure 45 Thousand kernel weight TKW (g) of wheat varieties stored in different bags/silos at Multan

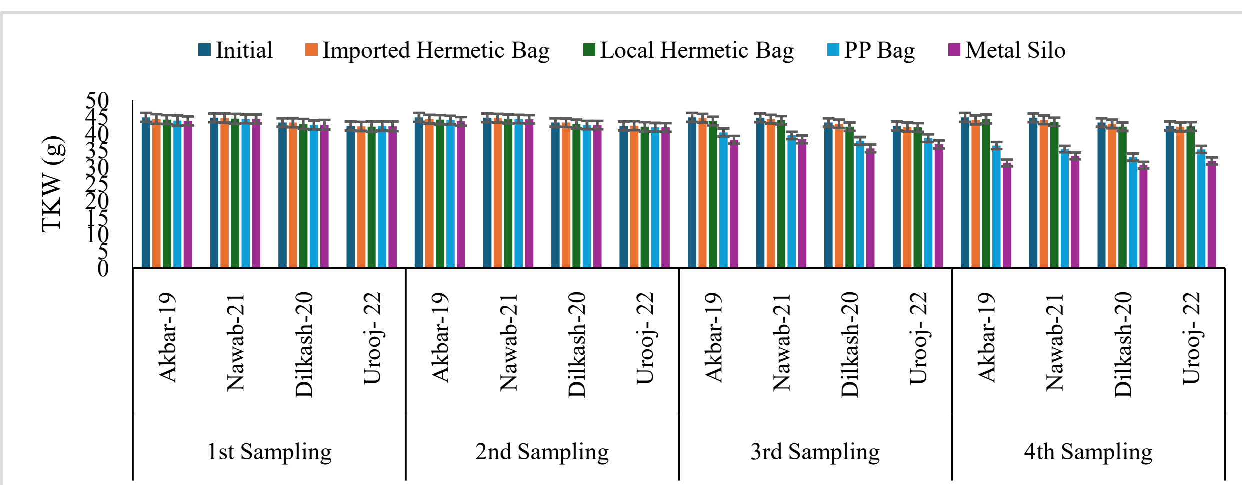


Figure 46 Thousand kernel weight TKW (g) of wheat varieties stored in different bags/silos at Khanewal I

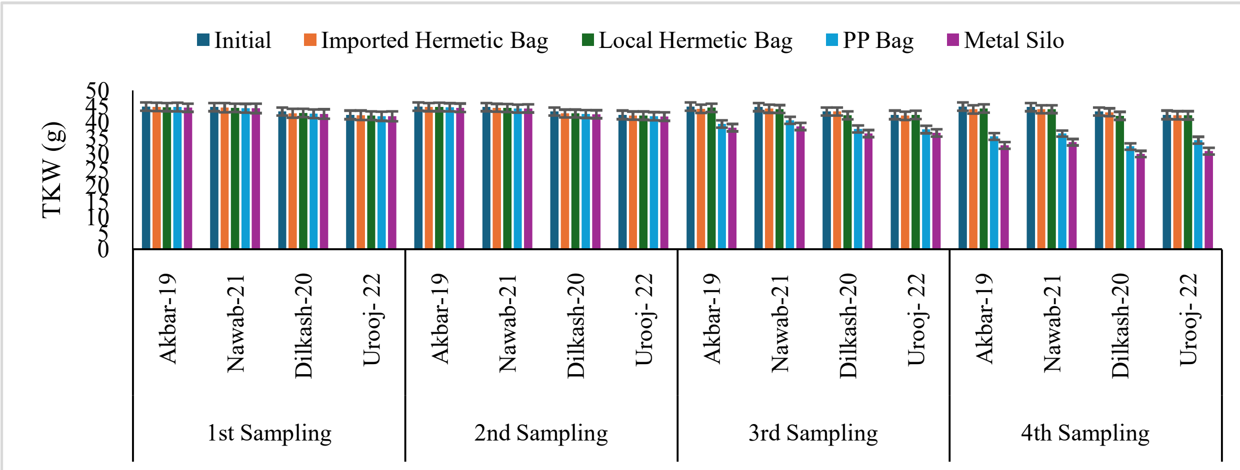


Figure 47 Thousand kernel weight TKW (g) of wheat varieties stored in different bags/silos at Khanewal II

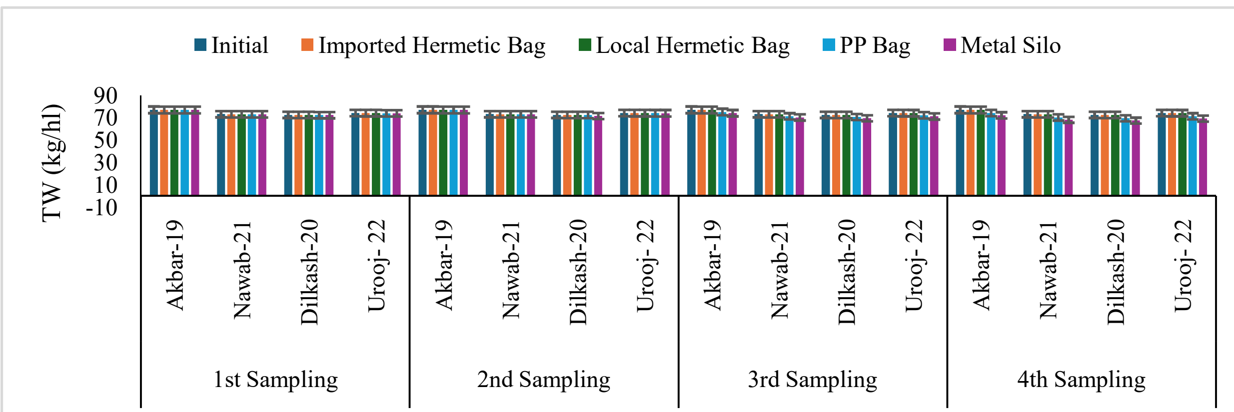


Figure 48 Test weight TW (kg)/hl) of wheat varieties stored in different bags/silos at Jalalpur

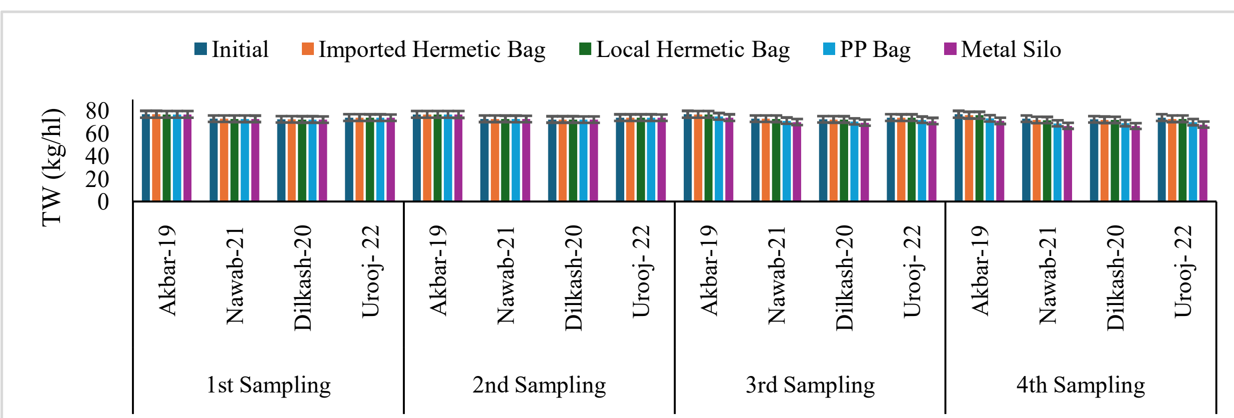


Figure 49 Test weight TW (kg)/hl) of wheat varieties stored in different bags/silos at Multan

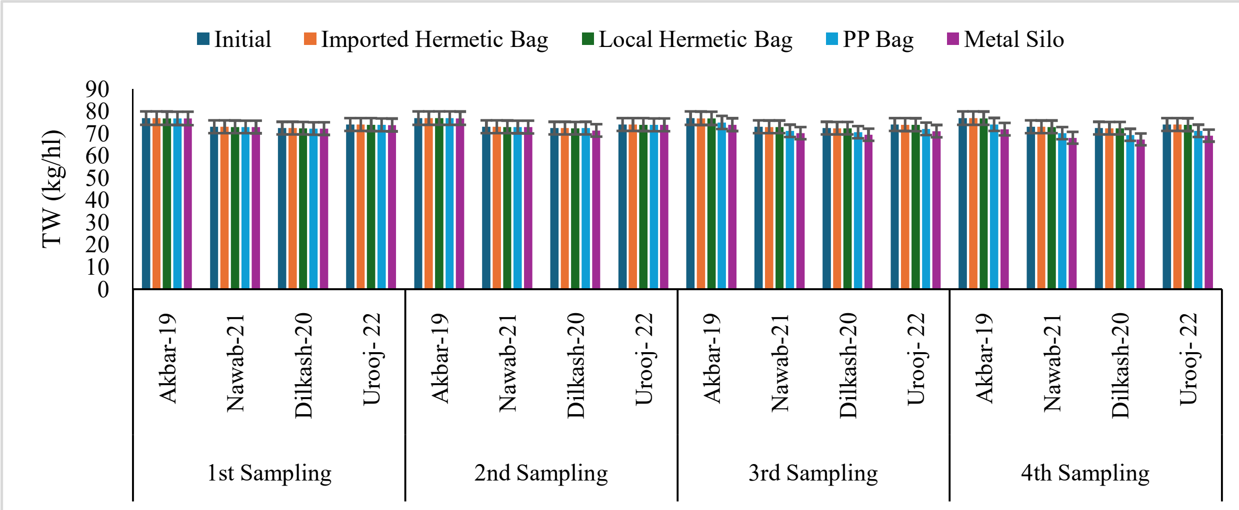


Figure 50 Test weight TW (kg)/hl) of wheat varieties stored in different bags/silos at Khanewal I

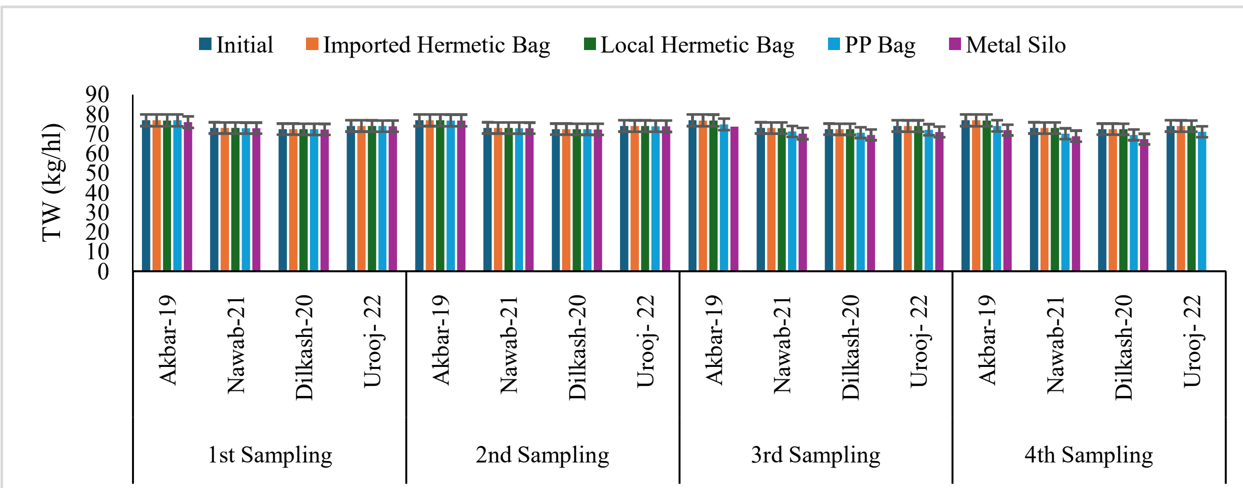


Figure 51 Test weight TW (kg)/hl) of wheat varieties stored in different bags/silos at Khanewal II

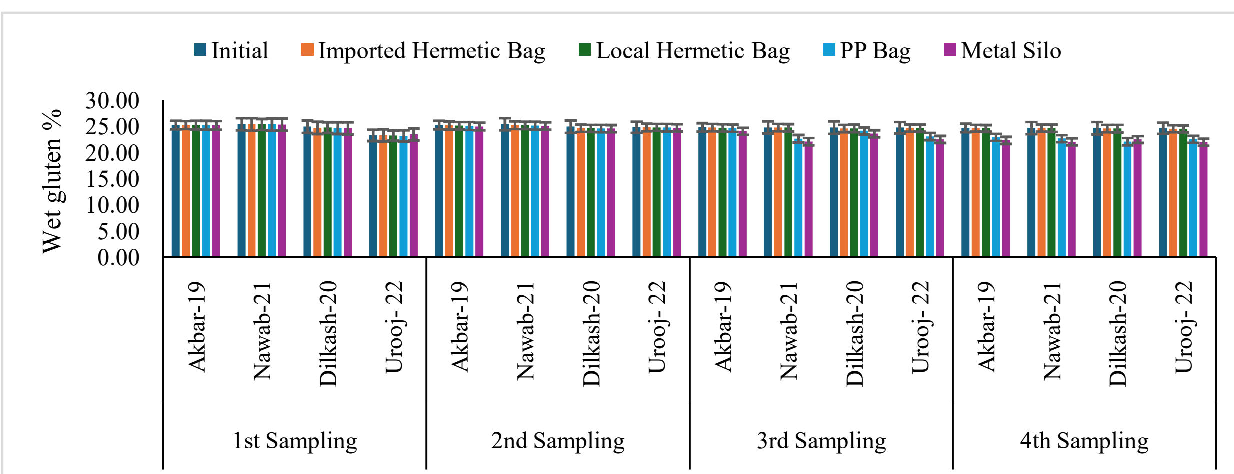


Figure 52 Wet Gluten (%) of wheat varieties stored in different bags/silos at Jalalpur

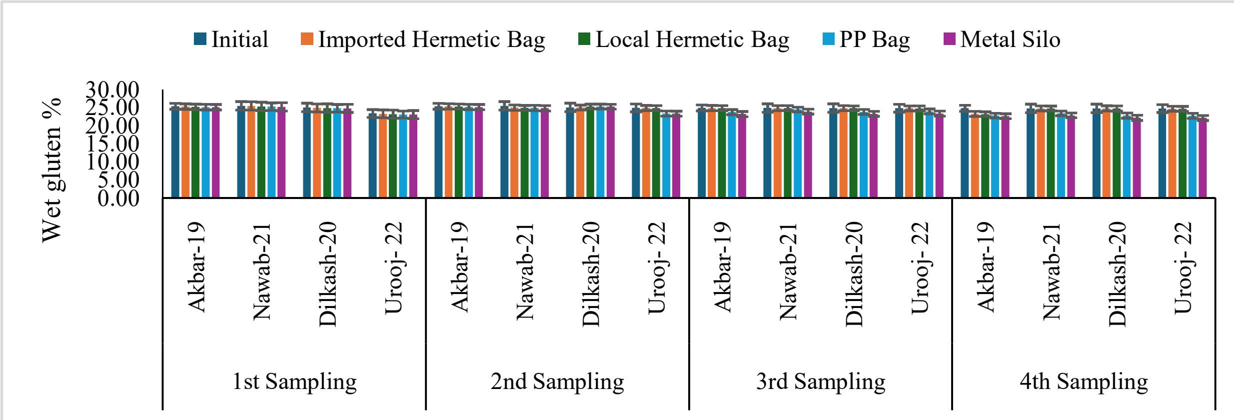


Figure 53 Wet Gluten (%) of wheat varieties stored in different bags/silos at Multan

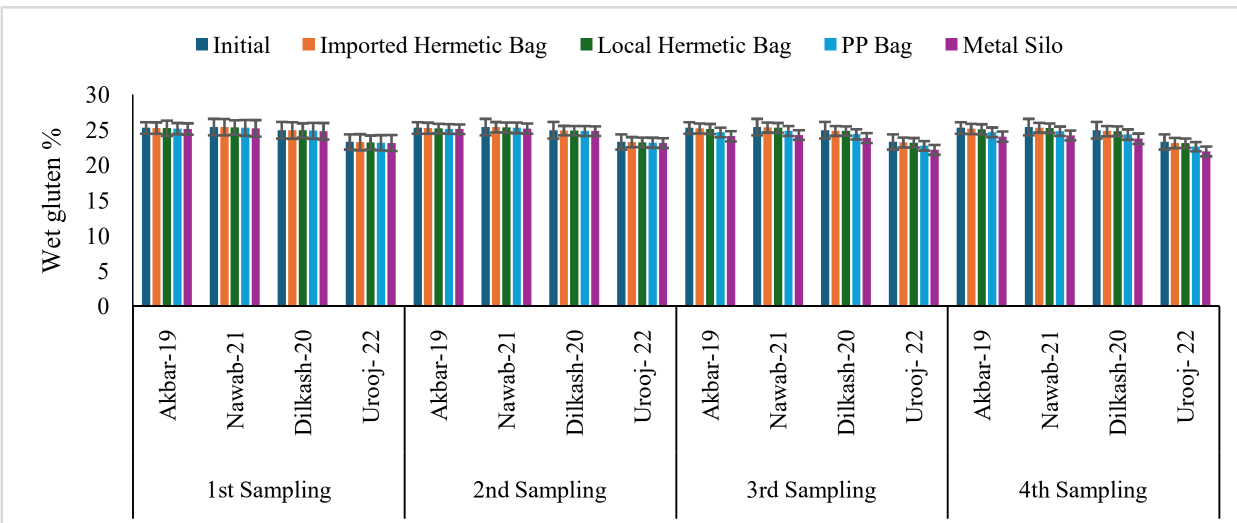


Figure 54 Wet Gluten (%) of wheat varieties stored in different bags/silos at Khanewal I

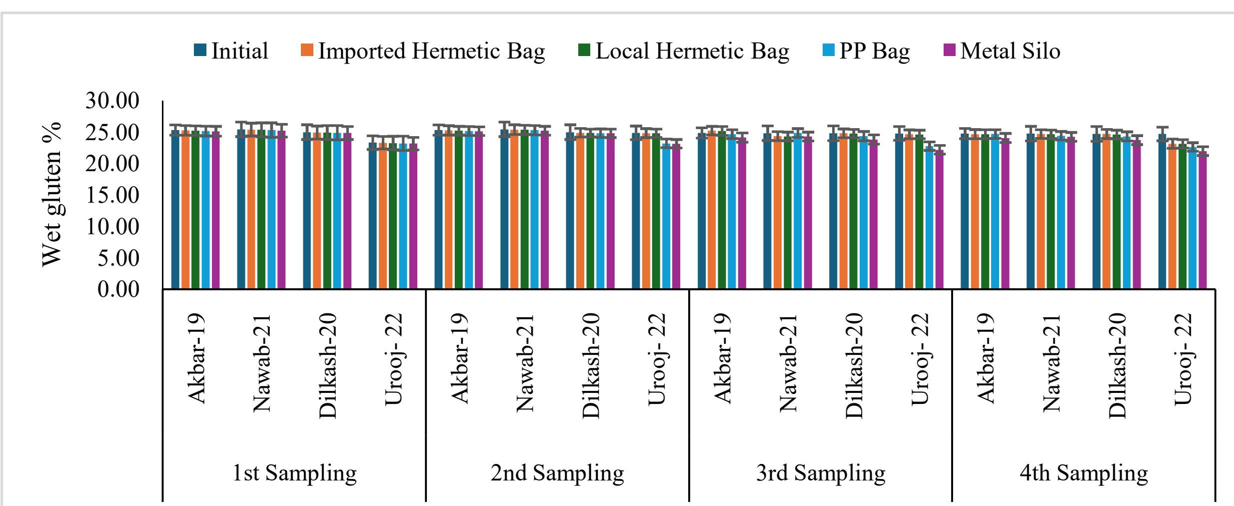


Figure 55 Wet Gluten (%) of wheat varieties stored in different bags/silos at Khanewal II

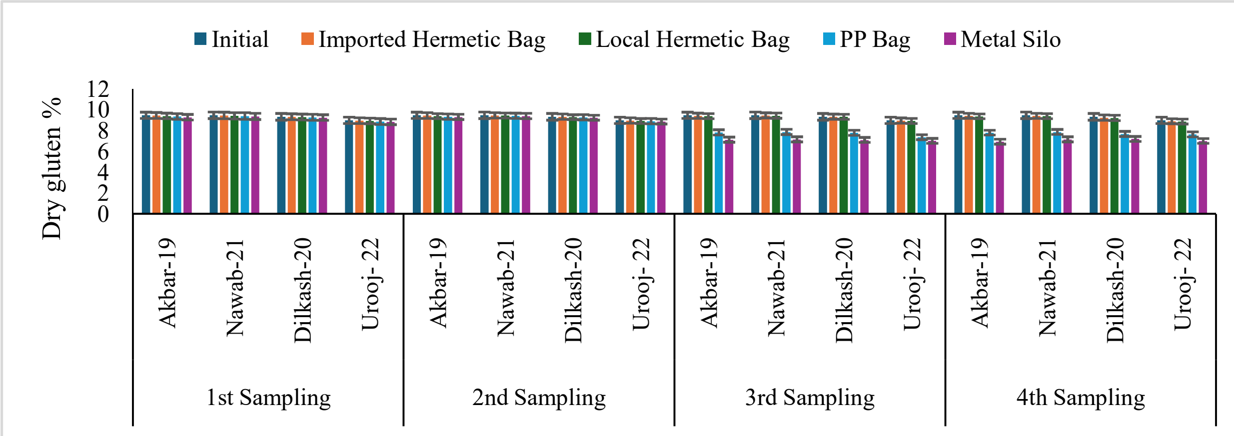


Figure 56 Dry Gluten (%) of wheat varieties stored in different bags/silos at Jalalpur

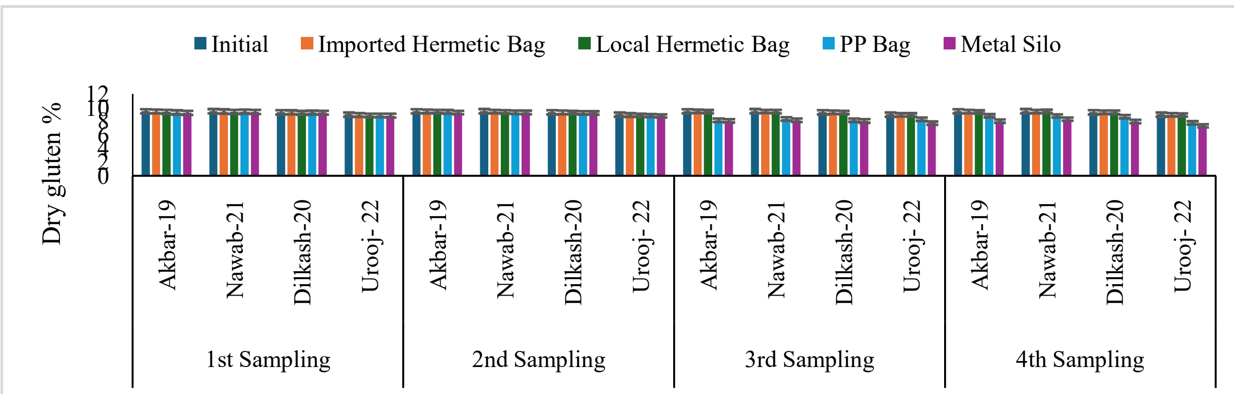


Figure 57 Dry Gluten (%) of wheat varieties stored in different bags/silos at Multan

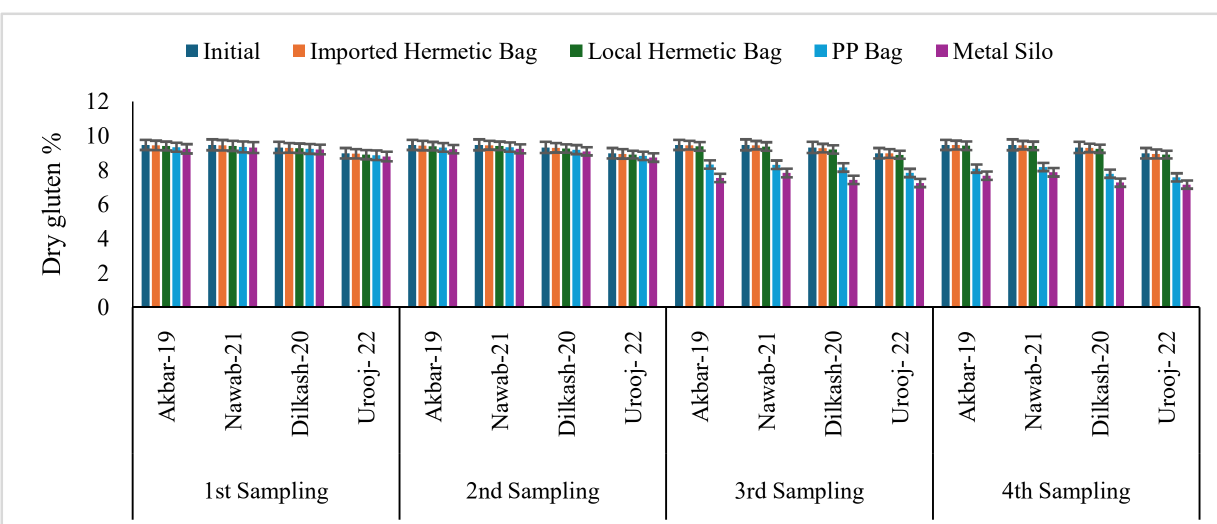


Figure 58 Dry Gluten (%) of wheat varieties stored in different bags/silos at Khanewal I

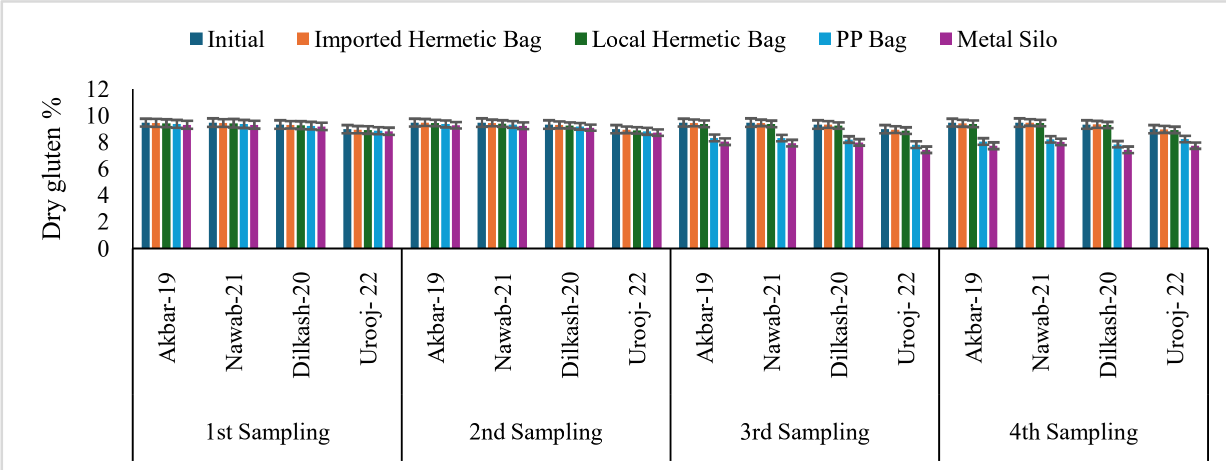


Figure 59 Dry Gluten (%) of wheat varieties stored in different bags/silos at Khanewal II

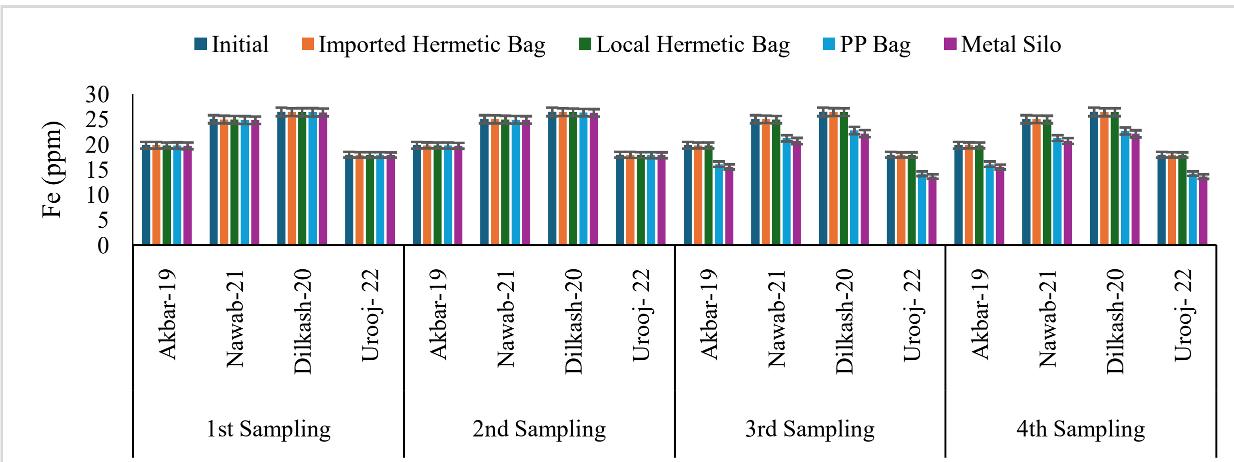


Figure 60 Fe content (ppm) of wheat varieties stored in different bags/silos at Jalalpur

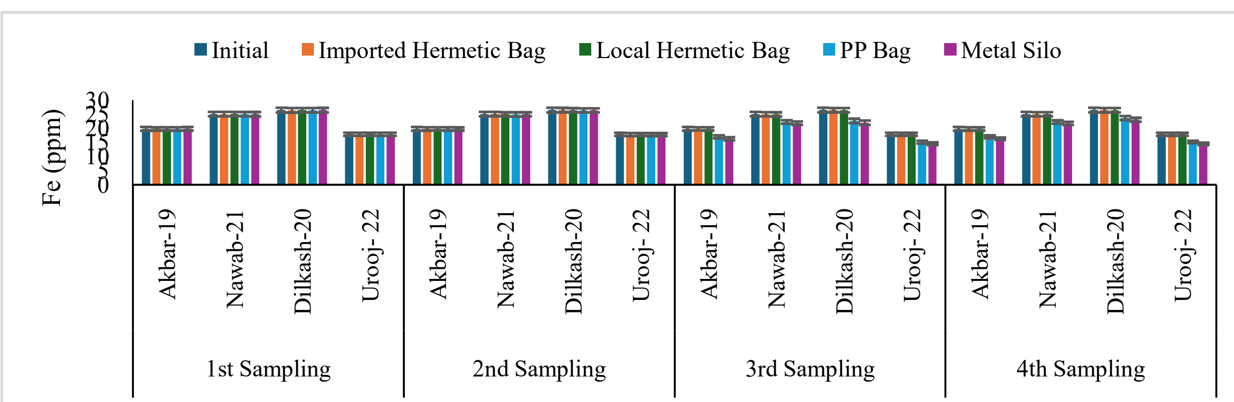


Figure 61 Fe content (ppm) of wheat varieties stored in different bags/silos at Multan

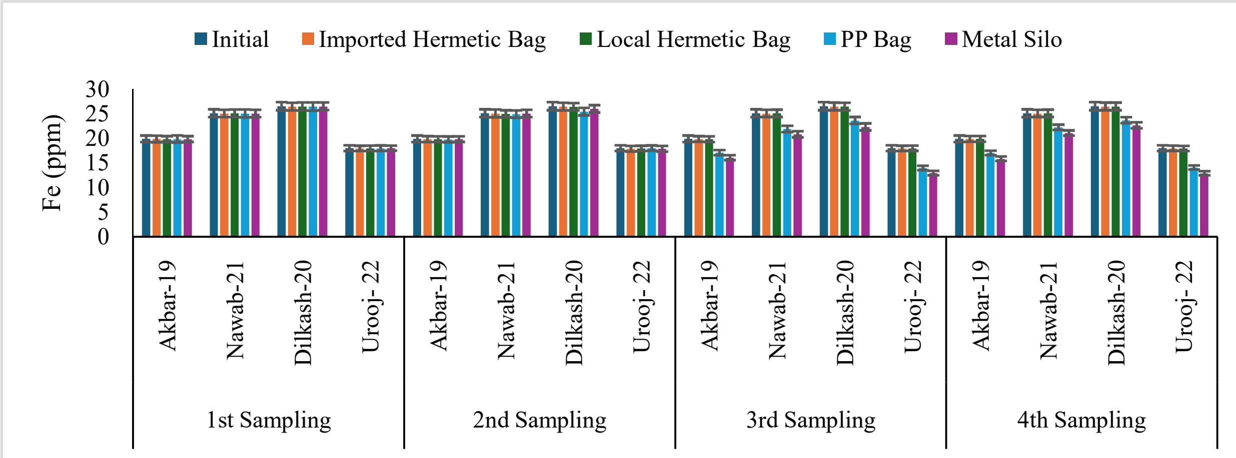


Figure 62 Fe content (ppm) of wheat varieties stored in different bags/silos at Khanewal I

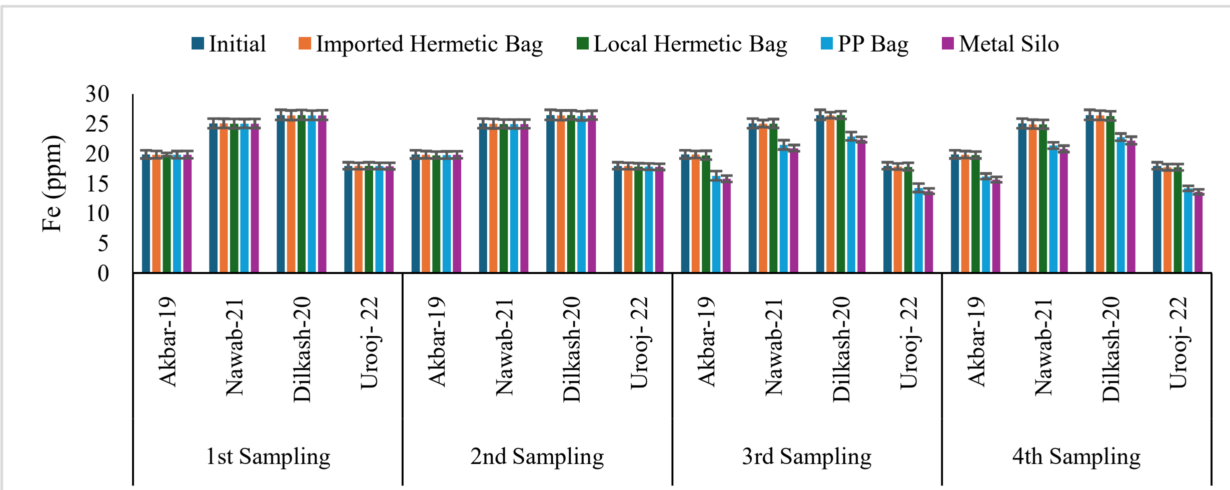


Figure 63 Fe content (ppm) of wheat varieties stored in different bags/silos at Khanewal II

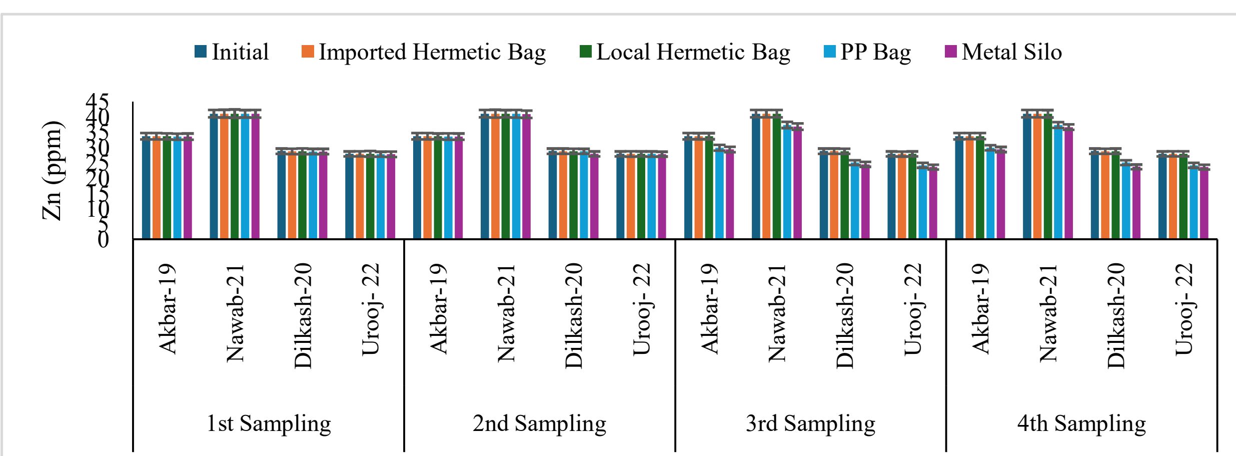


Figure 64 Zn content (ppm) of wheat varieties stored in different bags/silos at Jalalpur

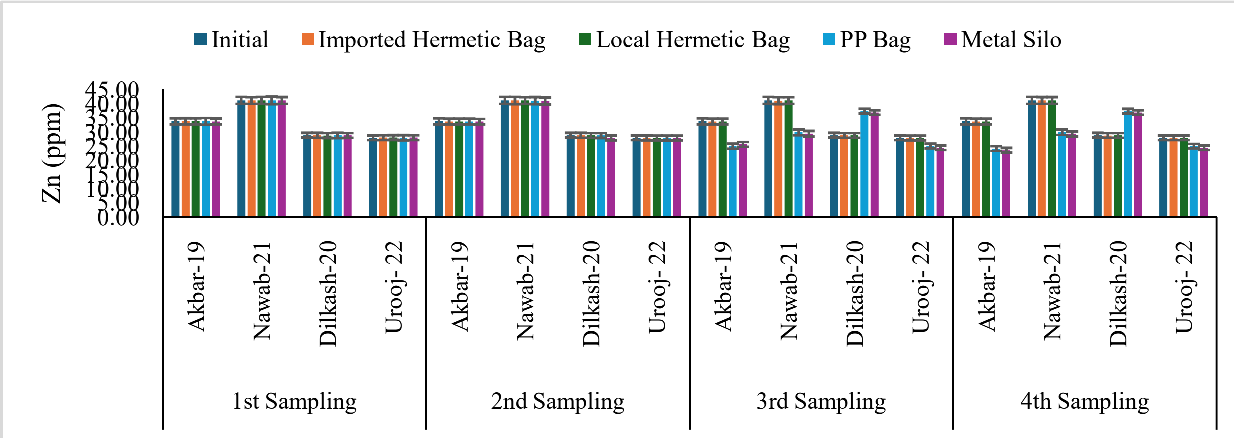


Figure 65 Zn content (ppm) of wheat varieties stored in different bags/silos at Multan

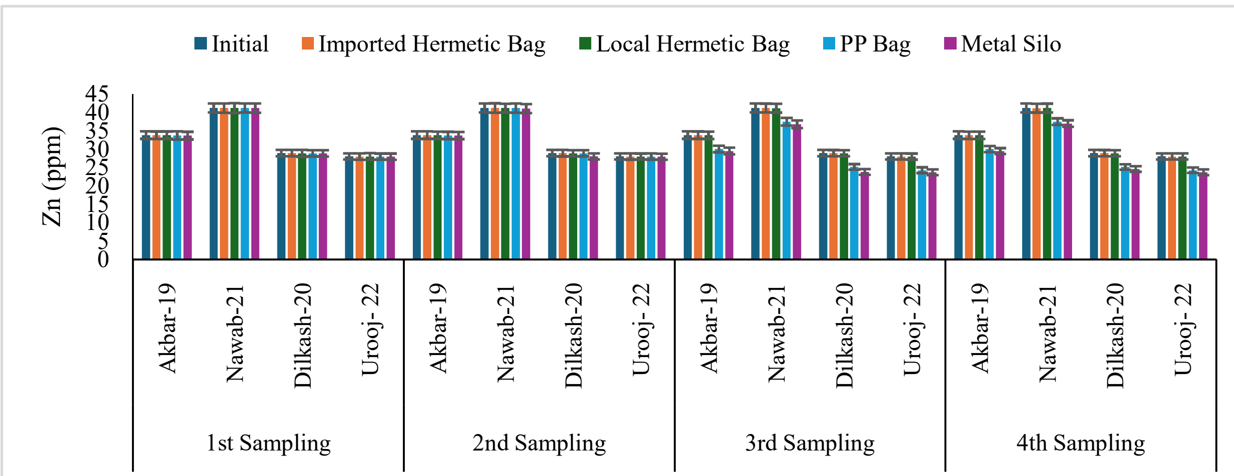


Figure 66 Zn content (ppm) of wheat varieties stored in different bags/silos at Khanewal I

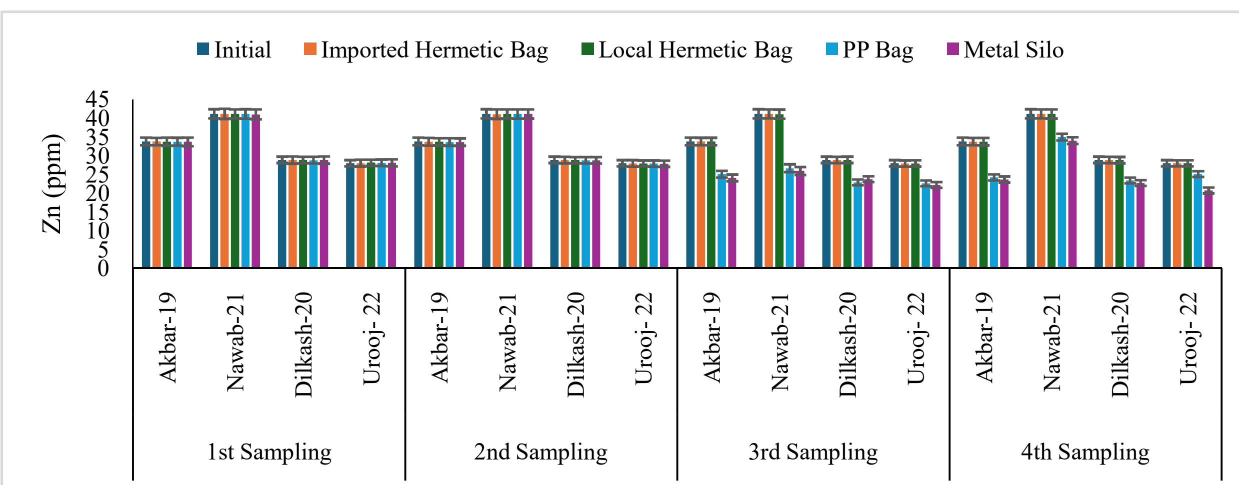


Figure 67 Zn content (ppm) of wheat varieties stored in different bags/silos at Khanewal II

10. Rheology Study

10.1 Water Absorption (%)

Results of water absorption varied in different storage structures after 12 months storage. Initially Akbar-19 had (53.40) water absorption. At Jalalpur, the highest water absorption (53.28) was recorded for the seed stored in imported hermetic bags while lowest water absorption (39.01) was recorded for the seed stored in iron silo. At Multan, local hermetic bags had the highest water absorption (53.29) while minimum water absorption (39.21) was recorded in iron silos. At Khanewal location I, the highest water absorption (53.36) was recorded for the seed stored in imported hermetic bags while lowest was (43.38) stored in iron silo. The lowest water absorption (39.37) recorded in iron silos while highest (53.16) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 68-71).

Water absorption varied in different storage structures after 12 months storage. Initially Nawab-21 had (54.20) water absorption. At Jalalpur location after 12 months sampling interval the highest water absorption (54.05) was in imported hermetic bags while lowest water absorption (39.79) was stored in iron silo (Figure 68-71). At Multan, imported hermetic bags had the highest water absorption (54.07%) while minimum water absorption (41.00) was recorded in iron silos. Khanewal location I, had the highest water absorption (54.15) in imported hermetic bags while lowest was (46.20) stored in iron silo. The lowest water absorption (43.99) recorded in iron silo while highest (53.94) in imported hermetic bags at Khanewal location II after 4th sampling.

Water absorption varied in different storage structures after 12 months storage. Initially Dilkash-20 had (52.70) water absorption. At Jalalpur location after 12 months sampling interval the highest water absorption (52.58) was in imported hermetic bags while lowest water absorption (38.37) was stored in iron silos (Figure 68-71). At Multan, imported hermetic bags had the highest water absorption (52.61) while minimum water absorption (38.59) was recorded in iron silo. Khanewal location I, had the highest water absorption (52.68) in imported hermetic bags while lowest was (42.72) stored in iron silo. The lowest water absorption (42.60) recorded in iron silos while highest (52.56) in imported hermetic bags at Khanewal location II after 4th sampling.

Initially Urooj-22 had initial water absorption (50.80). At Jalalpur location after 12 months sampling interval the highest water absorption (50.59) was in imported hermetic bags while lowest water absorption (34.44) was stored in iron silos. At Multan, imported hermetic bags had the highest water absorption (50.62) while minimum water absorption (36.60) was recorded in iron silo. Khanewal location I, had the highest water absorption (50.76) in imported hermetic bags while lowest was (37.80) stored in iron silo. The lowest water absorption (40.59) recorded in iron silos while highest (50.55) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 68-71).

10.2 Dough Development Time (DDT)

Results of dough development time varied in different storage structures after 12 months storage. Initially Akbar-19 had (4.35) dough development time. At Jalalpur, the highest dough development time (4.32) was recorded for the seed stored in imported hermetic bags while lowest dough development time (2.76) was recorded for the seed stored in iron silo. At Multan, local hermetic bags had the highest dough development time (4.33) while minimum dough development time (2.36) was recorded in iron silos (Figure 72-75). At Khanewal location I, the highest dough development time (4.33) was recorded for the seed stored in local hermetic bags while lowest was (3.18) stored in iron silo. The lowest dough development time (3.21) recorded in iron silos while highest (4.32) in imported hermetic bags at Khanewal location II after 4^{th} sampling.

Dough development time varied in different storage structures after 12 months storage. Initially Nawab-21 had (4.48) dough development time. At Jalalpur location after 12 months sampling interval the highest dough development time (4.43) was in imported hermetic bags while lowest dough development time (2.90) was stored in iron silo. At Multan, imported hermetic bags had the highest dough development time (4.42%) while minimum dough development time (2.50) was recorded in iron silos. Khanewal location I, had the highest dough development time (4.47) in local hermetic bags while lowest was (3.32) stored in iron silo. The lowest dough development time (3.24) recorded in iron silo while highest (4.43) in imported hermetic bags at Khanewal location II after 4^{th} sampling (Figure 72-75).

Dough development time varied in different storage structures after 12 months storage. Initially Dilkash-20 had (4.28) dough development time. At Jalalpur location after 12 months sampling interval the highest dough development time (4.29) was in local hermetic bags while lowest dough development time (2.67) was stored in iron silos. At Multan, imported hermetic bags had the highest dough development time (4.25) while minimum dough development time (2.27) was recorded in iron silo. Khanewal location I, had the highest dough development time (4.29) in imported hermetic bags while lowest was (3.16) stored in iron silo (Figure 72-75). The lowest dough development time (3.15) recorded in iron silos while highest (4.26) in imported hermetic bags at Khanewal location II after 4^{th} sampling.

Initially Urooj-22 had initial dough development time (4.22). At Jalalpur location after 12 months sampling interval the highest dough development time (4.2) was in imported hermetic bags while lowest dough development time (2.62) was stored in iron silos. At Multan, imported hermetic bags had the highest dough development time (4.19) while minimum dough development time (2.22) was recorded in iron silo. Khanewal location I, had the highest dough development time (4.21) in imported hermetic bags while lowest was (3.00) stored in iron silo. The lowest (3.03) recorded in iron silos while highest (4.20) in imported hermetic bags at Khanewal location II after 4^{th} sampling (Figure 72-75).

10.3 Dough Stability (DS (FU))

Results of dough stability varied in different storage structures after 12 months storage. Initially Akbar-19 had (5.55) dough stability. At Jalalpur, the highest dough stability (5.28) was recorded for the seed stored in imported hermetic bags while lowest dough stability (4.19) was recorded for the seed stored in iron silo. At Multan, local hermetic bags had the highest dough stability (5.48) while minimum dough stability (4.18) was recorded in iron silos. At Khanewal location I, the highest dough stability (5.27) was recorded for the seed stored in imported hermetic bags while lowest was (4.21) stored in iron silo (Figure 76-79). The lowest dough stability (4.19) recorded in PP bags while highest (5.49) in imported hermetic bags at Khanewal location II after 4th sampling.

Dough stability varied in different storage structures after 12 months storage. Initially Nawab-21 had (5.38) dough stability. At Jalalpur location after 12 months sampling interval the highest dough stability (5.27) was in imported hermetic bags while lowest dough stability (4.16) was stored in iron silo. At Multan, imported hermetic bags had the highest dough stability (5.27%) while minimum dough stability (4.37) was recorded in iron silos. Khanewal location I, had the highest dough stability (5.26) in imported hermetic bags while lowest was (4.27) stored in iron silo. The lowest dough stability (4.28) recorded in iron silo while highest (5.33) in imported hermetic bags at Khanewal location II after 4th sampling(Figure 76-79).

Dough stability varied in different storage structures after 12 months storage. Initially Dilkash-20 had (5.29) dough stability. At Jalalpur location after 12 months sampling interval the highest dough stability (5.27) was in imported hermetic bags while lowest dough stability (4.51) was stored in iron silos. At Multan, imported hermetic bags had the highest dough stability (5.25) while minimum dough stability (4.12) was recorded in iron silo. Khanewal location I, had the highest dough stability (5.49) in imported hermetic bags while lowest was (4.12) stored in iron silo. The lowest dough stability (4.11) recorded in iron silos while highest (5.26) in imported hermetic bags at Khanewal location II after 4th sampling(Figure 76-79).

Initially Urooj-22 had initial dough stability (5.32). At Jalalpur location after 12 months sampling interval the highest dough stability (5.34) was in imported hermetic bags while lowest dough stability (4.30) was stored in iron silos. At Multan, imported hermetic bags had the highest dough stability (5.3) while minimum dough stability (4.27) was recorded in iron silo(Figure 76-79). Khanewal location I, had the highest dough stability (5.33) in imported hermetic bags while lowest was (4.10) stored in iron silo. The lowest (4.15) recorded in iron silos while highest (5.28) in imported hermetic bags at Khanewal location II after 4th sampling.

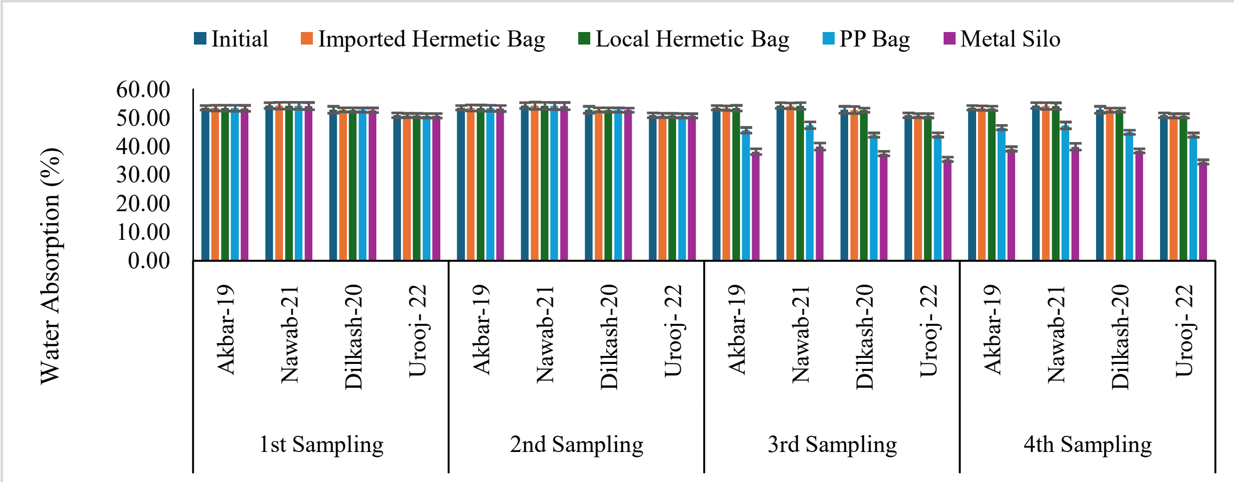


Figure 68 Water absorption (%) of wheat varieties stored in different bags/silos at Jalalpur

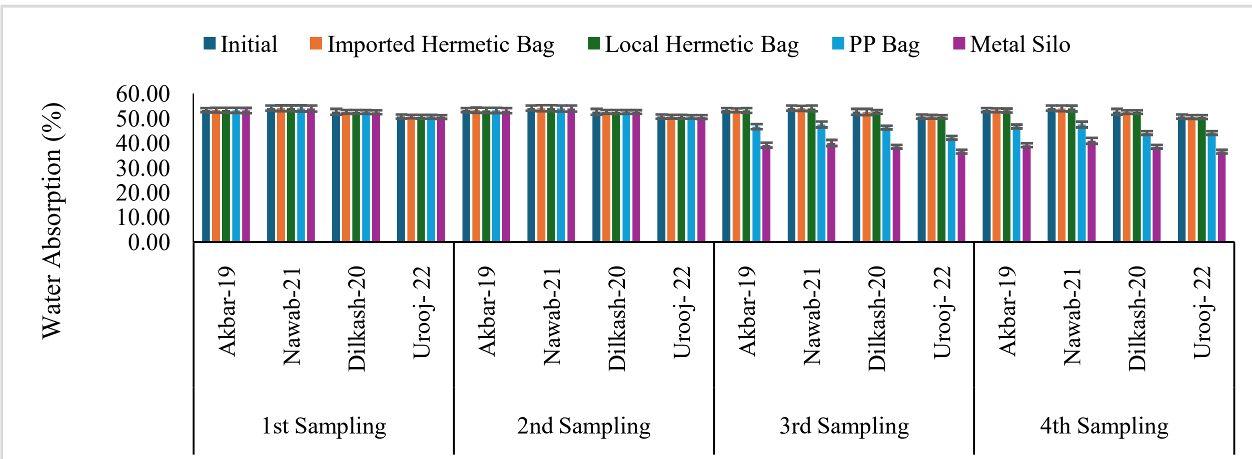


Figure 69 Water absorption (%) of wheat varieties stored in different bags/silos at Multan

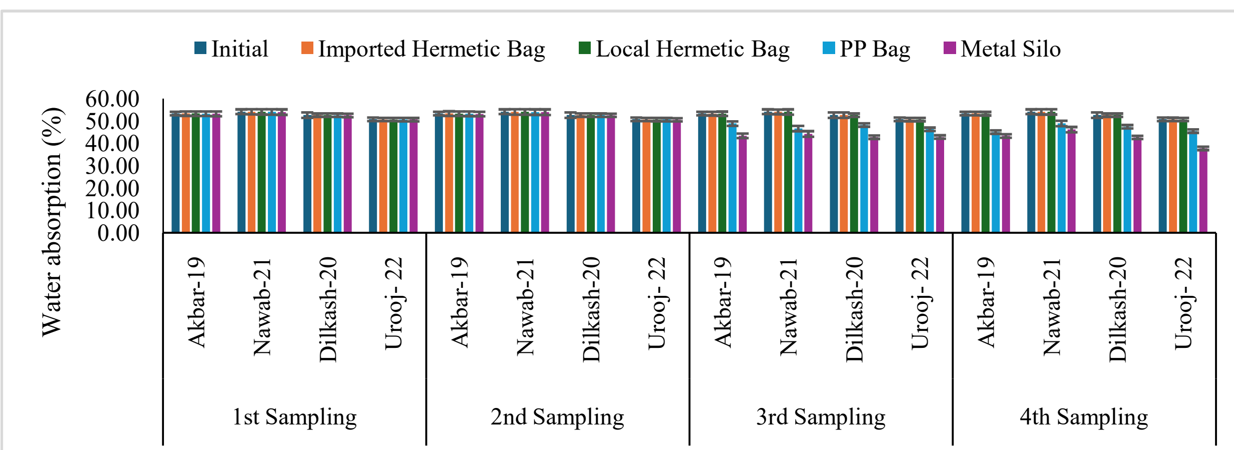


Figure 70 Water absorption (%) of wheat varieties stored in different bags/silos at Khanewal I

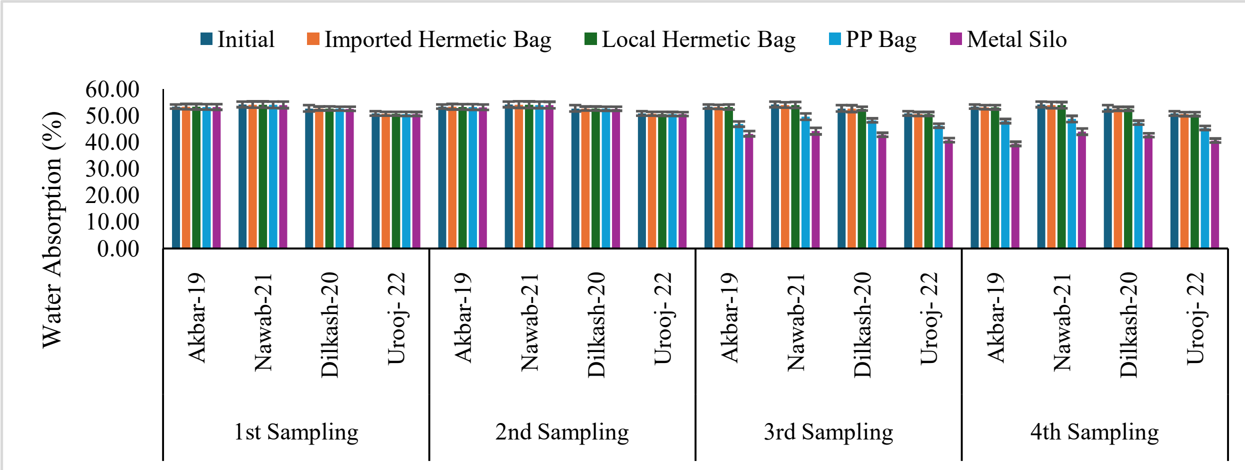


Figure 71 Water absorption (%) of wheat varieties stored in different bags/silos at Khanewal II

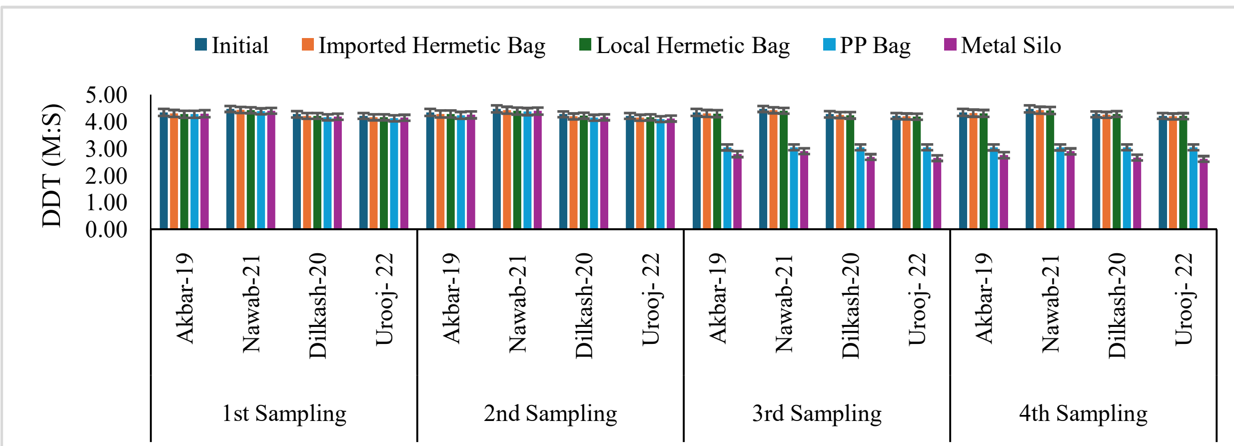


Figure 72 Dough development time (min) of wheat varieties stored in different bags/silos at Jalalpur

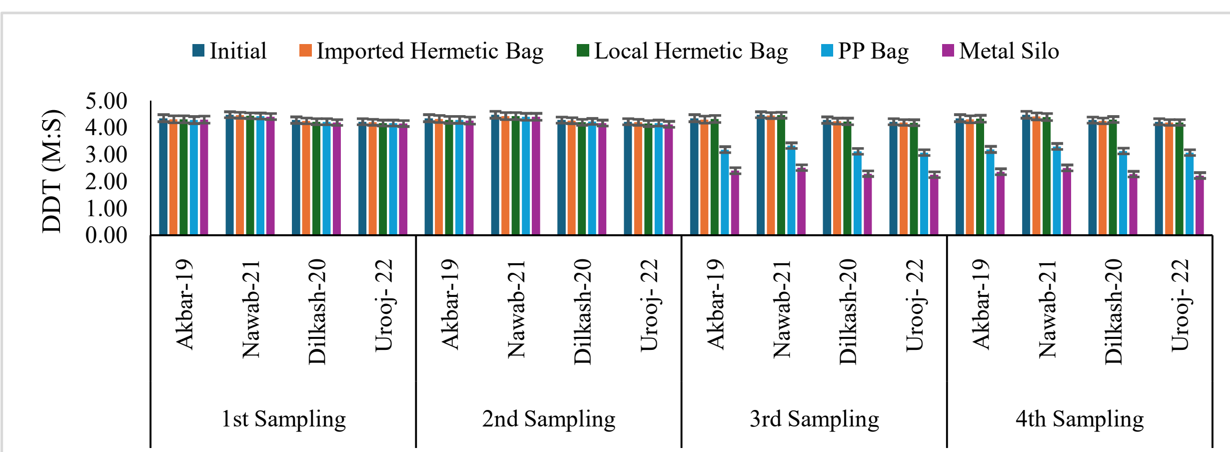


Figure 73 Dough development time (min) of wheat varieties stored in different bags/silos at Multan

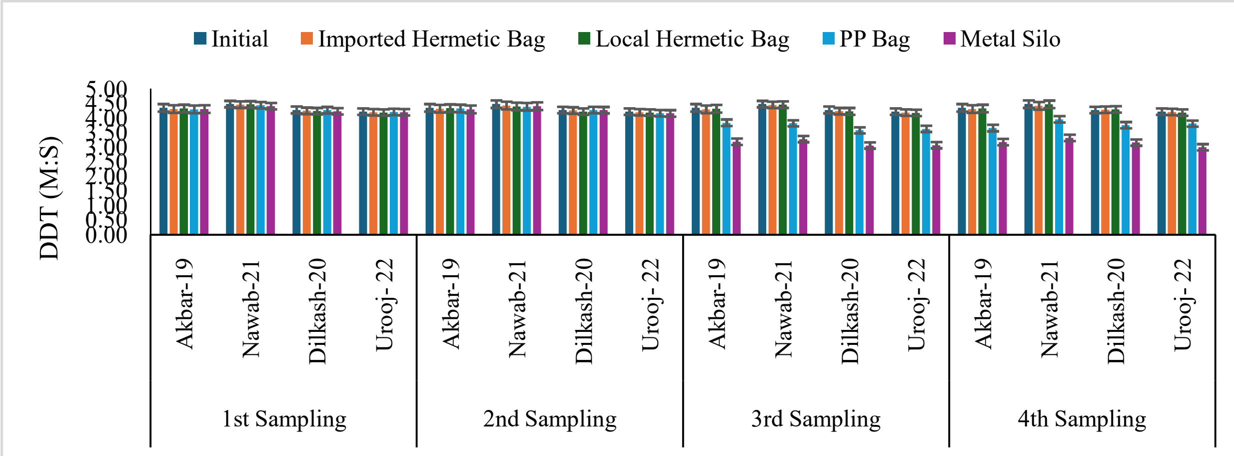


Figure 74 Dough development time (min) of wheat varieties stored in different bags/silos at Khanewal I

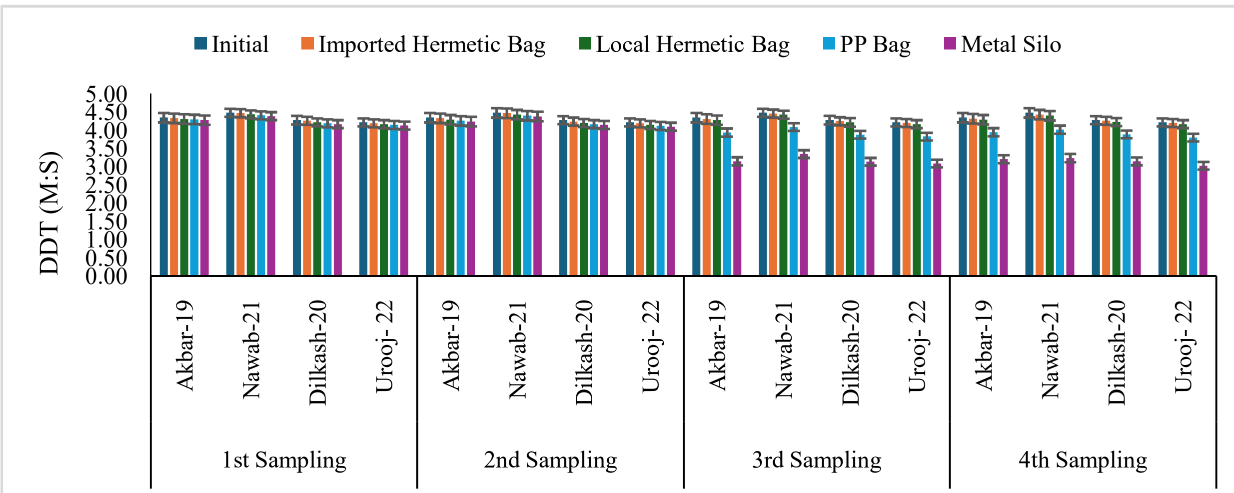


Figure 75 Dough development time (min) of wheat varieties stored in different bags/silos at Khanewal II

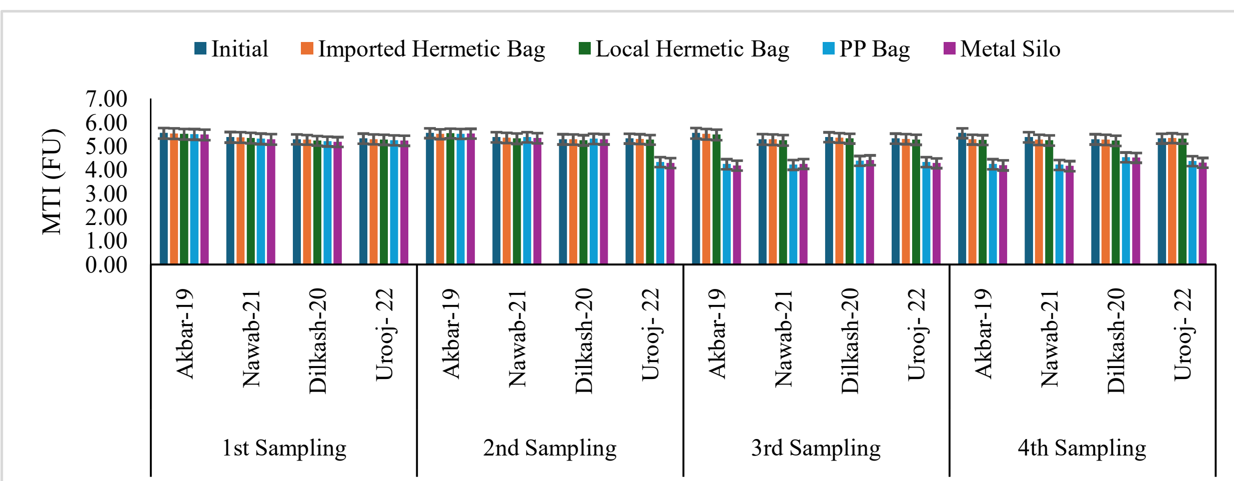


Figure 76 Dough stability (min) of wheat varieties stored in different bags/silos at Jalalpur

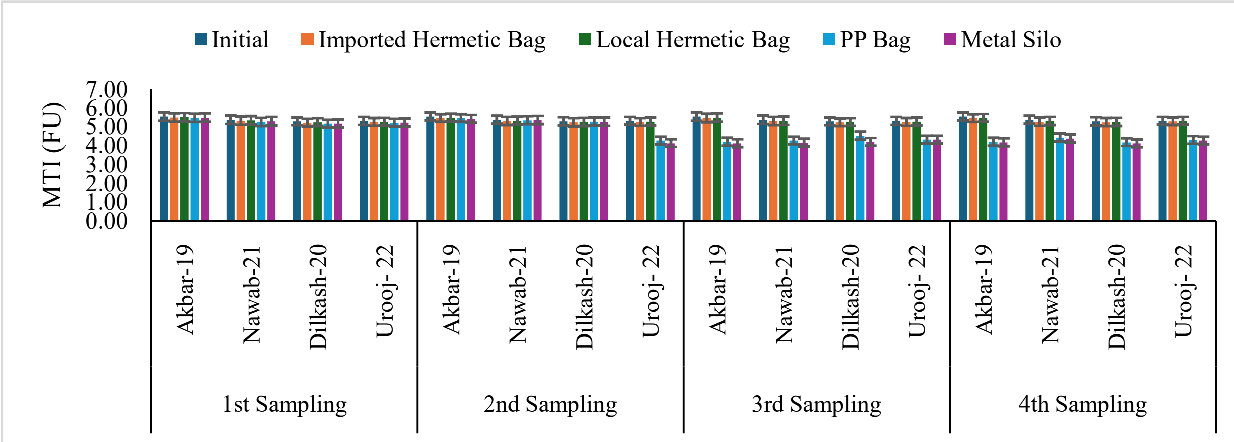


Figure 77 Dough stability (min) of wheat varieties stored in different bags/silos at Multan

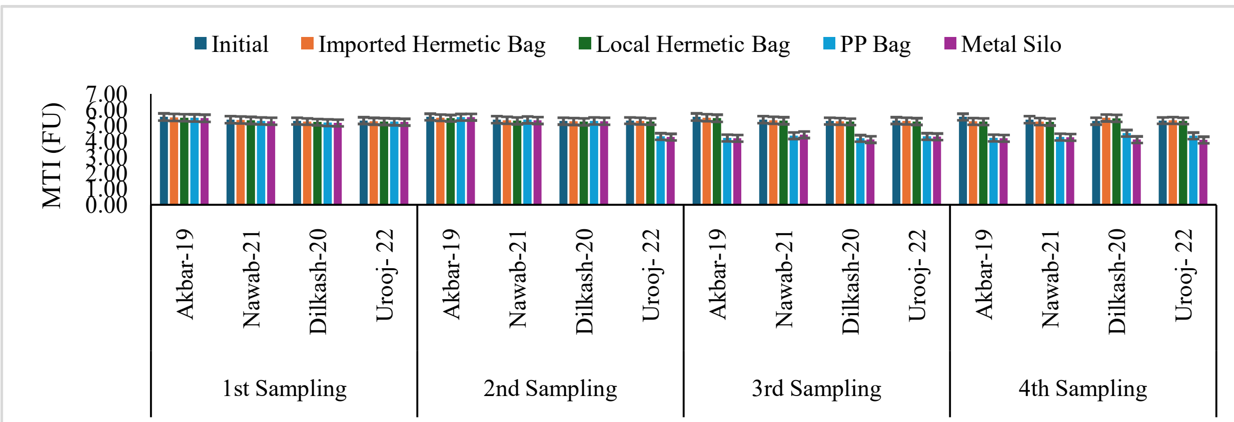


Figure 78 Dough stability (min) of wheat varieties stored in different bags/silos at Khanewal I

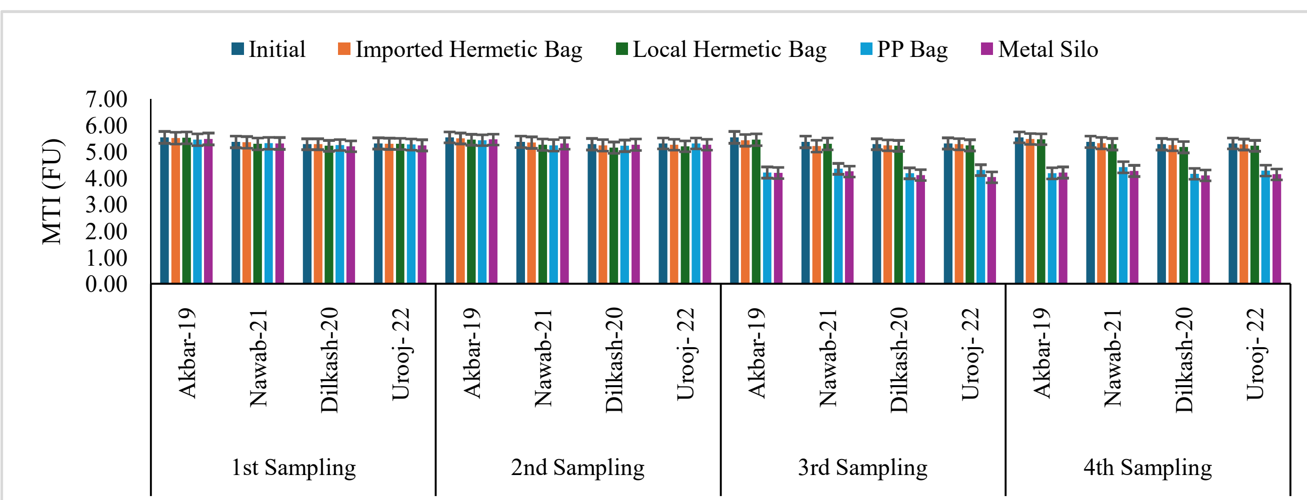


Figure 79 Dough stability (min) of wheat varieties stored in different bags/silos at Khanewal II

11. Results of Products

11. 1 Iron contents (ppm) in Chapatti

Results of iron content varied before and after storage in various storage techniques. Initially iron was recorded to be (20.86 ppm) in Akbar-19. At Khanewal location I, the highest iron content (20.82 ppm) was recorded to be in imported hermetic bags and lowest was recorded (17.19 ppm) in iron silo (Figure 80-83). Similarly, in Khanewal location II, the highest iron content was recorded (20.84 ppm) in imported hermetic bags and lowest iron content was (17.01 ppm) recorded to be in iron silo. In Multan, the lowest iron content was (18.80 ppm) in iron silo and was highest (18.75 ppm) in imported hermetic bags. At Jalalpur, the highest iron content was (20.81 ppm) recorded in imported hermetic bags and lowest iron content was recorded to be (15.75 ppm) in iron silo during 4th sampling.

After 12 months storage, initially iron was recorded to be (24.15 ppm) in Nawab-21. At Khanewal location I, the highest iron content (24.12 ppm) was recorded to be in imported hermetic bags and lowest was recorded (21.44 ppm) in iron silo. Similarly, in Khanewal location II, the highest iron content was recorded (22.14 ppm) in imported hermetic bags and lowest iron content was (19.86 ppm) recorded to be in iron silo. In Multan, the lowest iron content was (20.71 ppm) in iron silo and highest was (23.72 ppm) in imported hermetic bags (Figure 80-83). At Jalalpur, the highest iron content was (24.06 ppm) recorded in imported hermetic bags and lowest iron content was recorded to be (20.24 ppm) in iron silo during 4th sampling.

In Dilkash-20, After 12 months storage, initially iron was recorded to be (25.47 ppm). At Khanewal location I, the highest iron content (25.33 ppm) was recorded to be in local hermetic bags and lowest was recorded (23.08 ppm) in iron silo. Similarly, in Khanewal location II, the highest iron content was recorded (24.42 ppm) in imported hermetic bags and lowest iron content was (20.41 ppm) recorded to be in iron silo (Figure 54). In Multan, the lowest iron content was (19.91 ppm) in iron silo and highest iron content was (24.61 ppm) in local hermetic bags. At Jalalpur, the highest iron content was (25.26 ppm) recorded in imported hermetic bags and lowest iron content was recorded to be (21.41ppm) in iron silo during 4th sampling (Figure 80-83).

Initially iron content was recorded to be (18.96 ppm) in Urooj-22. At Khanewal location I, the highest iron content (18.94 ppm) after storage was recorded in imported hermetic bags and lowest was recorded (15.54 ppm) in iron silo. Similarly, at Khanewal location II, the highest iron content was recorded (18.93 ppm) in imported hermetic bags and lowest iron content was (15.92 ppm) recorded to be in iron silo. At Multan, the lowest iron content was (15.19 ppm) in iron silo and highest content was (18.85 ppm) in imported hermetic bags. At Jalalpur, the highest iron content was (18.91 ppm) recorded in imported hermetic bags and lowest iron content was recorded to be (14.29 ppm) in iron silo at 4^{th} sampling (Figure 80-83).

11.2 Zinc contents (ppm) in Chapatti

Results of zinc content varied after 12 months of storage in various storage techniques. Initially zinc contents in Akbar-19 were 33.73 ppm. At Khanewal location I, the highest zinc content (33.73 ppm) was recorded to be in imported hermetic bags and lowest was recorded (29.35 ppm) in iron silo (Figure 84-87). Similarly, in Khanewal location II, the highest zinc content was recorded (32.58 ppm) in imported hermetic bags and lowest zinc content was (27.11 ppm) recorded to be in iron silo. In Multan, the lowest zinc content was (30.51 ppm) in iron silo and highest content was (32.92 ppm) in local hermetic bags. At Jalalpur, the highest zinc content was (32.66 ppm) recorded in imported hermetic bags and lowest zinc content was recorded to be (29.01 ppm) in iron silo during 4th sampling.

In Nawab-21, initially zinc was recorded to be 39.17 ppm. At Khanewal location I, the highest zinc content (39.05 ppm) was recorded to be in imported hermetic bags and lowest was recorded (34.51 ppm) in iron silo. Similarly, in Khanewal location II, the highest zinc content was recorded (39.12 ppm) in imported hermetic bags and lowest zinc content was (36.21 ppm) recorded to be in iron silo. In Multan, the lowest zinc content was (35.51 ppm) in iron silo and highest content was (39.14 ppm) in imported hermetic bags (Figure 84-87). At Jalalpur, the highest zinc content was (39.17 ppm) recorded in imported hermetic bags and lowest zinc content was recorded to be (36.01 ppm) in iron silo during 4th sampling.

Initially zinc was recorded to be (26.8 ppm) in Dilkash-20. At Khanewal location I, the highest zinc content (25.78 ppm) was recorded to be in local hermetic bags and lowest was recorded (22.91 ppm) in iron silo (Figure 84-87). Similarly, in Khanewal location II, the highest zinc content was recorded (25.09 ppm) in imported hermetic bags and lowest zinc content was (20.31 ppm) recorded to be in iron silo. In Multan, the lowest zinc content was (22.31 ppm) in iron silo and highest content was (26.8 ppm) in imported hermetic bags. At Jalalpur, the highest zinc content was (24.84 ppm) recorded in imported hermetic bags and lowest zinc content was recorded to be (21.41ppm) in iron silo at 4th sampling.

Zinc contents were (25.89 ppm) in Urooj-22 before storage. At Khanewal location I, the highest zinc content (25.44 ppm) was recorded to be in imported hermetic bags and lowest was recorded (21.51 ppm) in iron silo. Similarly, in Khanewal location II, the highest zinc content was recorded (25.13 ppm) in imported hermetic bags and lowest zinc content was (21.21 ppm) recorded to be in iron silo. In Multan, the lowest zinc content was (21.01 ppm) in iron silo and highest content was (25.20 ppm) in imported hermetic bags. At Jalalpur, the highest zinc content was (25.18 ppm) recorded in imported hermetic bags and lowest zinc content was recorded to be (22.11 ppm) in iron silo during 4th sampling (Figure 84-87).

11.3 Iron contents (ppm) in biscuits

Results of iron content varied in different storage structures after 12 months storage. Initially Akbar-19 had (20.81 ppm) iron content. At Jalalpur, the highest iron content (19.676 ppm) was recorded for the seed stored in imported hermetic bags while lowest iron content (15.57 ppm) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest iron content (20.77 ppm) while minimum iron content (15.86 ppm) was recorded in iron silos. At Khanewal location I, the highest iron content (20.78 ppm) was recorded for the seed stored in imported hermetic bags while lowest was (18.69 ppm) stored in iron silo. The lowest iron content (16.56 ppm) recorded in iron silos while highest (20.78 ppm) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 88-91).

Iron content varied in different storage structures after 12 months storage. Initially Nawab-21 had (24.19 ppm) iron content. At Jalalpur location after 12 months sampling interval the highest iron content (24.08 ppm) was in imported hermetic bags while lowest iron content (23.66 ppm) was stored in iron silo. At Multan, local hermetic bags had the highest iron content (24.14 ppm) while minimum iron content (19.92 ppm) was recorded in iron silo. Khanewal location I, had the highest iron content (24.15 ppm) in local hermetic bags while lowest was (22.52 ppm) stored in iron silo. The lowest iron content (20.67 ppm) recorded in iron silo while highest (24.15%) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 88-91).

Iron content varied in different storage structures after 12 months storage. Initially Dilkash-20 had (25.63 ppm) iron content. At Jalalpur location after 12 months sampling interval the highest iron content (24.18 ppm) was in imported hermetic bags while lowest iron content (20.28 ppm) was stored in iron silo. At Multan, imported hermetic bags had the highest iron content (25.58 ppm) while minimum iron content (21.81 ppm) was recorded in iron silo. Khanewal location I, had the highest iron content (25.58 ppm) in imported hermetic bags while lowest was (23.57 ppm) stored in iron silo. The lowest iron content (20.24 ppm) recorded in iron silos while highest (25.56 ppm) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 88-91).

Initially Urooj-22 had (17.96 ppm) iron content. At Jalalpur location after 12 months sampling interval the highest iron content (17.87 ppm) was in imported hermetic bags while lowest iron content (14.02 ppm) was stored in iron silos. At Multan, imported hermetic bags had the highest iron content (17.91 ppm) while minimum iron content (12.75 ppm) was recorded in iron silo. Khanewal location I, had the highest iron content (17.93 ppm) in imported hermetic bags while lowest was (15.34 ppm) stored in iron silo. The lowest iron content (13.62 ppm) recorded in iron silos while highest (17.91 ppm) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 88-91).

11.4 Zinc contents (ppm) in biscuits

Results of zinc content varied in different storage structures after 12 months storage. Initially Akbar-19 had (33.66 ppm) zinc content. At Jalalpur, the highest zinc content (33.88 ppm) was recorded for the seed stored in imported hermetic bags while lowest zinc content (30.50 ppm) was recorded for the seed stored in iron silos. At Multan, imported hermetic bags had the highest zinc content (33.26 ppm) while minimum zinc content (27.68 ppm) was recorded in iron silos. At Khanewal location I, the highest zinc content (33.28 ppm) was recorded for the seed stored in imported hermetic bags while lowest was (29.73 ppm) stored in iron silo. The lowest zinc content (29.80 ppm) recorded in iron silos while highest (32.63 ppm) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 92-95).

Zinc content varied in different storage structures after 12 months storage. Initially Nawab-21 had (39.24 ppm) zinc content. At Jalalpur location after 12 months storage, the highest zinc content (39.15 ppm) was in imported hermetic bags while lowest zinc content (36.77 ppm) was stored in iron silo. At Multan, imported hermetic bags had the highest zinc content (39.17 ppm) while minimum zinc content (35.04 ppm) was recorded in iron silo. Khanewal location I, had the highest zinc content (38.98 ppm) in imported hermetic bags while lowest was (34.25 ppm) stored in iron silo (Figure 92-95). The lowest zinc content (35.40 ppm) recorded in iron silo while highest (39.14 ppm) in imported hermetic bags at Khanewal location II after 4th sampling.

Zinc content varied in different storage structures after 12 months storage. Initially Dilkash-20 had (26.91 ppm) zinc content. At Jalalpur location after 12 months storage, interval the highest zinc content (25.49 ppm) was in local hermetic bags while lowest zinc content (21.14 ppm) was stored in iron silo. At Multan, imported hermetic bags had the highest zinc content (26.12 ppm) while minimum zinc content (20.74 ppm) was recorded in iron silo. At Khanewal location I, the highest zinc contents (26.08 ppm) were recorded from the seed stored in imported hermetic bags while lowest was (21.98%) stored in iron silo. The lowest zinc content (21.90 ppm) recorded in iron silos while highest (25.11 ppm) in imported hermetic bags at Khanewal location II after 4th sampling (Figure 92-95).

Initially Urooj-22 had (25.76 ppm) zinc content. At Jalalpur location after 12 months sampling interval the highest zinc content (25.13 ppm) was in imported hermetic bags while lowest zinc content (19.23 ppm) was stored in iron silos (Figure 92-95). At Multan, imported hermetic bags had the highest zinc content (25.48 ppm) while minimum iron content (20.29 ppm) was recorded in iron silo. Khanewal location I, had the highest zinc content (25.09 ppm) in imported hermetic bags while lowest was (22.13 ppm) stored in iron silo. The lowest zinc content (20.02%) recorded in iron silos while highest (25.18 ppm) in imported hermetic bags at Khanewal location II after 4th sampling.

12 Sensory evaluations

12.1 Sensory evaluation of Biscuits

In Arooj-22, initially color was recorded to be 6.83 and its highest value after storage was recorded (6.8) in local hermetic bags and lowest (5.2) in iron silo. Similarly in Akbar-19, initial value was (7.4) highest value (7.5) in local hermetic bags and lowest (5.3) in PP bags. In Nawab-21, initially color was recorded to be (6.44). Highest was recorded to be (6.9) in imported hermetic bags and lowest (5.7) in iron silo. In Dilkash-20, initial value was recorded to be (6.11). Its highest value was (6.8) in imported hermetic bags and lowest was (4.7) in iron silo (Figure 96).

In Arooj-22, initially the texture was recorded to be 6.33. And its highest value was recorded (6.6) in PP bags and lowest (5.6) in iron silo. Similarly in Akbar-19, initially the texture was (4.4), highest value (6.8) in local hermetic bags and lowest (4.9) in iron silo (Figure 96). In Nawab-21, initially texture was recorded to be (6.44). Highest was recorded to be (6.9) in PP bags and lowest (5.2) in iron silo. And in Dilkash-20, initial value was recorded to be (6.56). Its highest value was recorded (6.3) in iron silo and lowest was (4.2) in PP bags.

In Arooj-22, initially taste was recorded to be 7.28. And its highest value was recorded (6.5) in imported hermetic bags and lowest (4.7) in iron silo. Similarly in Akbar-19, the initial taste was (5.4), highest value (6.5) in local hermetic bags and lowest (4.7) in PP bags. In Nawab-21, initially taste was recorded to be (7). Highest was recorded to be (6.6) in PP bags and lowest (5.3) in iron silo. And in Dilkash-20, initial value was recorded to be (6.89). Its highest value was recorded (6) in imported hermetic and lowest was (4.5) in local hermetic bags (Figure 96).

In Arooj-22, initially appearance was recorded to be 6.89. And its highest value was recorded (6.5) in PP bag and lowest (5.6) in iron silo. Similarly in Akbar-19, initial appearance was (5.6), highest value (7.3) in local hermetic bags and lowest (5.5) in iron silo. In Nawab-21, initial appearance was recorded to be (7.11). Highest was recorded to be (7.2) in local hermetic bags and lowest (5.8) in iron silo. And in Dilkash-20, initial value was recorded to be (6.11). Its highest value was recorded (7.1) in imported hermetic and lowest was (4.3) in PP bags (Figure 96).

In Arooj-22, initially overall acceptability was recorded to be 7.44. And its highest value was recorded (6.8) in PP bags and lowest (6.1) in iron silo. Similarly in Akbar-19, initially overall acceptability was (6), highest value (6.7) in local hermetic bags and lowest (5.2) in PP bags. In Nawab-21, initially overall acceptability was recorded to be (7.67). The highest was recorded to be (6.6) in imported hermetic bags and lowest (6.1) in iron silo (Figure 96). And in Dilkash-20, initial value was recorded to be (6.61). Its highest value was recorded (7) in imported hermetic and lowest was (4.4) in iron silo.

In Arooj-22, initially the flavor was recorded to be 7.00. And its highest value was recorded (6.4) in imported hermetic bags and lowest (5) in iron silo. Similarly in Akbar-19, initially flavor was (5.7), highest value (6.3) in local hermetic bags and lowest (4.7) in iron silo. In Nawab-21, initially flavor was recorded to be (6.89). Highest was recorded to be (6.5) in PP bags and lowest (5) in iron silo. And in Dilkash-20, initial value was recorded to be (6.56). Its highest value was recorded (6.5) in PP bags and lowest was (4.5) in iron silo (Figure 96).

12.2 **Sensory evaluation of Chapatti**

In Arooj-22, initially color was recorded to be 6.88. And its highest value was recorded (6.4) in imported hermetic bags and lowest (5.2) in PP bags. Similarly in Akbar-19, initials value was (7.88), highest value (6.6) in iron silo and lowest (5.7) in PP bags. In Nawab-21, initially color was recorded to be (7.22). Highest was recorded to be (6.5) in iron silo and lowest (5) in local hermetic bags. And in Dilkash-20, initial value was recorded to be (5.11). Its highest value was (5.5) in PP bags and lowest was (5.1) in imported hermetic bags (Figure 97).

In Arooj-22, initially texture was recorded to be 6.88. And its highest value was recorded (6.2) in PP bags and lowest (5.4) in local hermetic bags. Similarly in Akbar-19, initially texture was (7.22), highest value (6.7) in local hermetic bags and lowest (5.9) in imported hermetic bags. In Nawab-21, initially texture was recorded to be (7.44). Highest was recorded to be (6.7) in imported hermetic bags and lowest (5.4) in iron silo (Figure 97). And in Dilkash-20, initial value was recorded to be (5.32). Its highest value was recorded (5.6) in iron silo and lowest was (4.5) in local hermetic bags.

In Arooj-22, the initial taste was recorded to be 7.22. And its highest value was recorded (6.7) in PP bag and lowest (6.1) in iron silo. Similarly in Akbar-19, initially taste was (7.00), highest value (6.9) in local hermetic bags and lowest (5.4) in imported hermetic bags. In Nawab-21, initially taste was recorded to be (7.22). Highest was recorded to be (6.8) in PP bags and lowest (5.5) in iron silo. And in Dilkash-20, initial value was recorded to be (5.77). Its highest value was recorded (4.8) in imported hermetic and lowest was (4.1) in imported hermetic bags (Figure 97).

In Arooj-22, initial appearance was recorded to be 6.66. And its highest value was recorded (6.7) in local hermetic bags and lowest (5.4) in imported bags. Similarly in Akbar-19, initially appearance was (7.55), highest value (6.9) in PP and iron bags and lowest (6.7) in imported hermetic bags. In Nawab-21, initial appearance was recorded to be (7.11). Highest was recorded to be (7.2) in imported hermetic bags and lowest (5.3) in iron silo. And in Dilkash-20, initial value was recorded to be (5.88). Its highest value was recorded (5.0) in imported hermetic products and lowest was (4.4) in local hermetic bags (Figure 97).

In Arooj-22, initially overall acceptability was recorded to be 7.33. And its highest value was recorded (6.9) in local hermetic bags and lowest (5.5) in imported hermetic bags. Similarly in Akbar-19, initially overall acceptability was (7.44), the highest value (6.4) in iron silo and lowest (5.4) in PP bags. In Nawab-21, initially overall acceptability was recorded to be (7.77). Highest was recorded to be (7) in PP bags and lowest (5.8) in iron silo (Figure 97). And in Dilkash-20, initial value was recorded to be (5.55). Its highest value was recorded (5.2) in local hermetic and lowest was (4.7) in iron silo.

In Arooj-22, initially flavor was recorded to be 7.22. And its highest value was recorded (6.5) in iron silo and lowest (5.7) in PP bags. Similarly in Akbar-19, initially flavor was (7.44), highest value (6.7) in PP bags and lowest (5.4) in imported hermetic bags. In Nawab-21, initially flavor was recorded to be (7.22). The highest was recorded to be (6.7) in PP bags and lowest (5.6) in imported hermetic bags. And in Dilkash-20, initial value was recorded to be (5.44). Its highest value was recorded (5) in PP bags and lowest was (4.1) in imported hermetic bags (Figure 97).

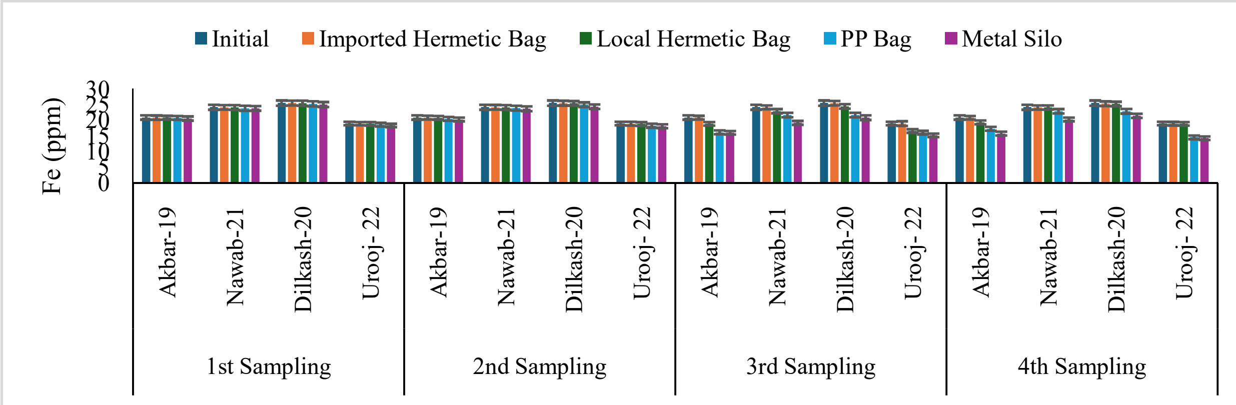


Figure 80 Iron content (ppm) in chapatti prepared from wheat varieties stored in different bags/silos at Jalalpur

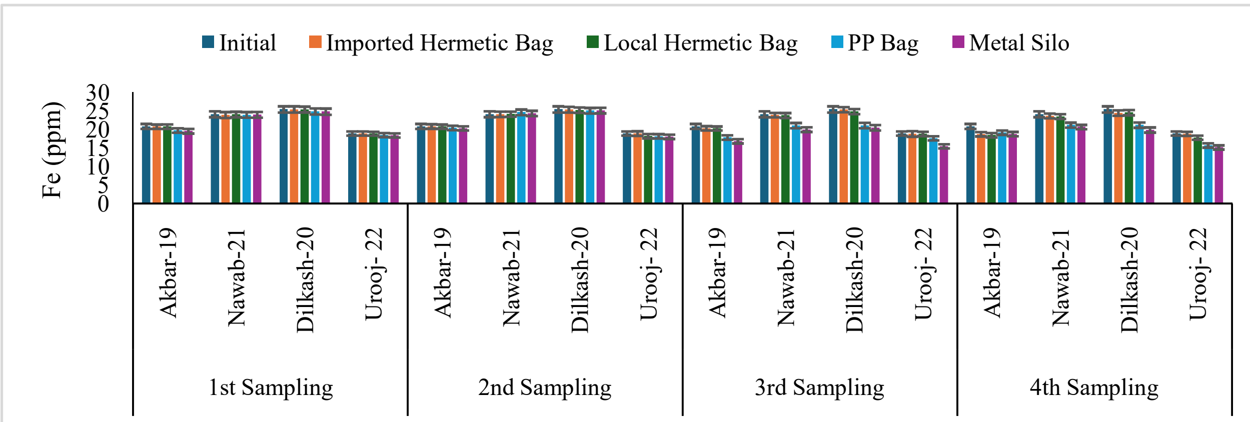


Figure 81 Iron content (ppm) in chapatti prepared from wheat varieties stored in different bags/silos at Multan

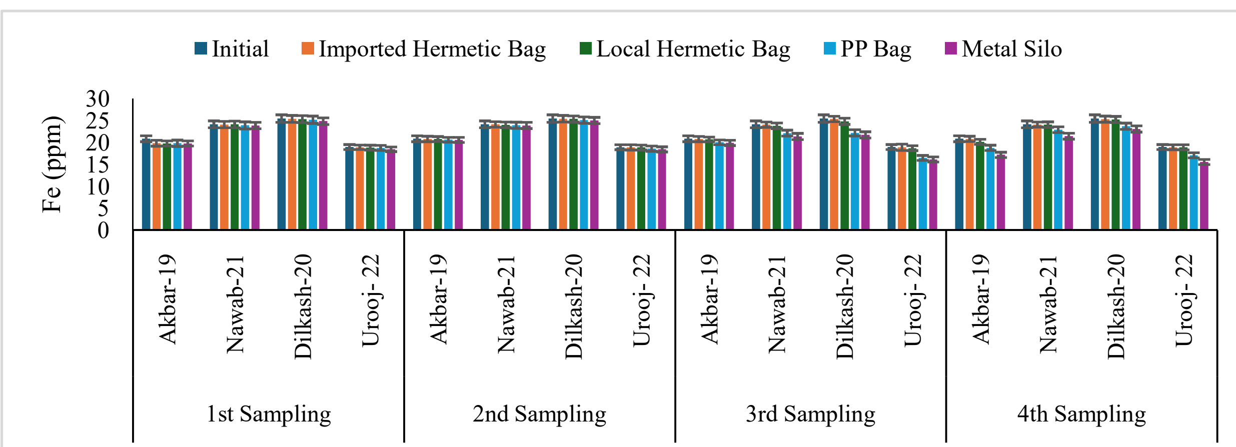


Figure 82 Iron content (ppm) in chapatti prepared from wheat varieties stored in different bags/silos at Khanewal I

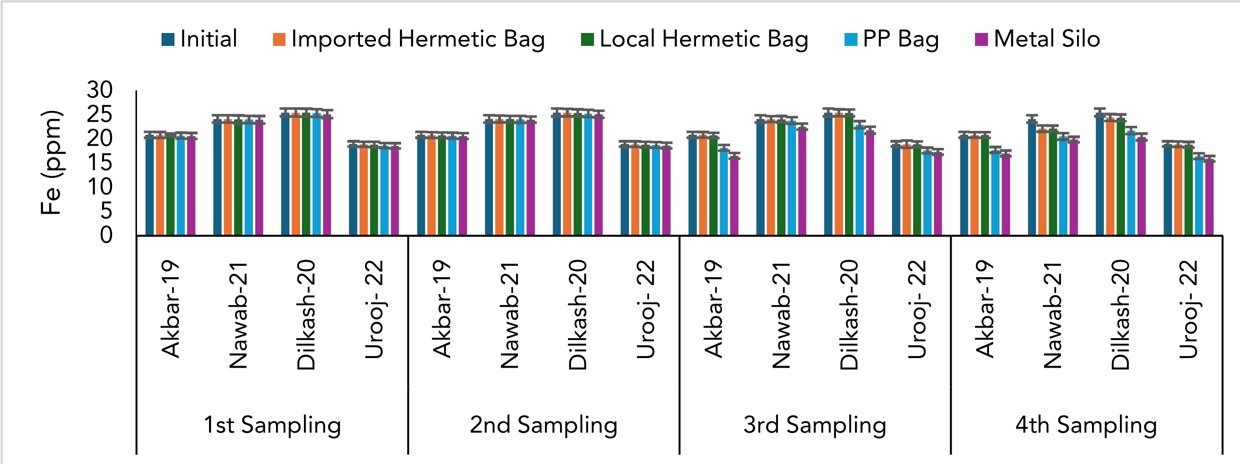


Figure 83 Iron content (ppm) in chapatti prepared from wheat varieties stored in different bags/silos at Khanewal II

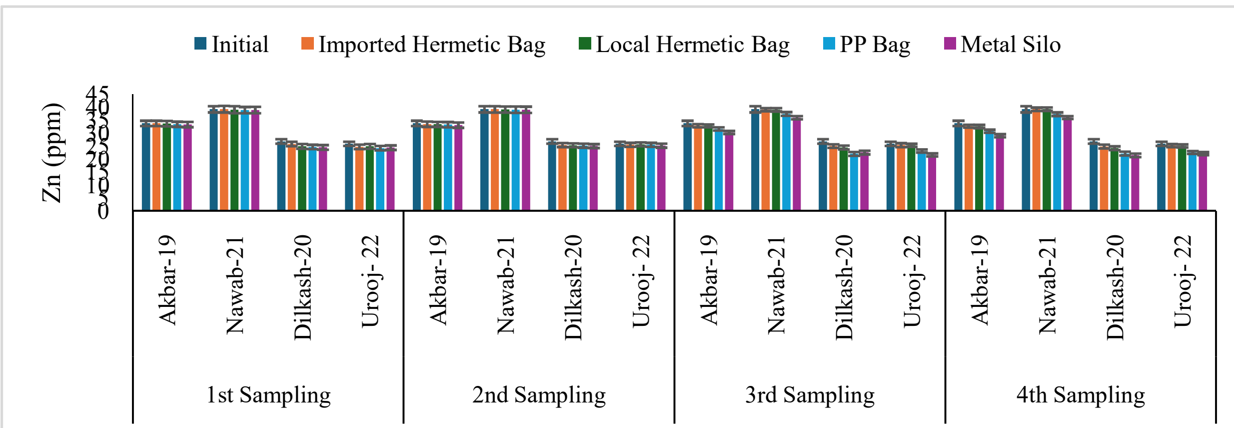


Figure 84 Zn content (ppm) in chapatti prepared from wheat varieties stored in different bags/silos at Jalalpur

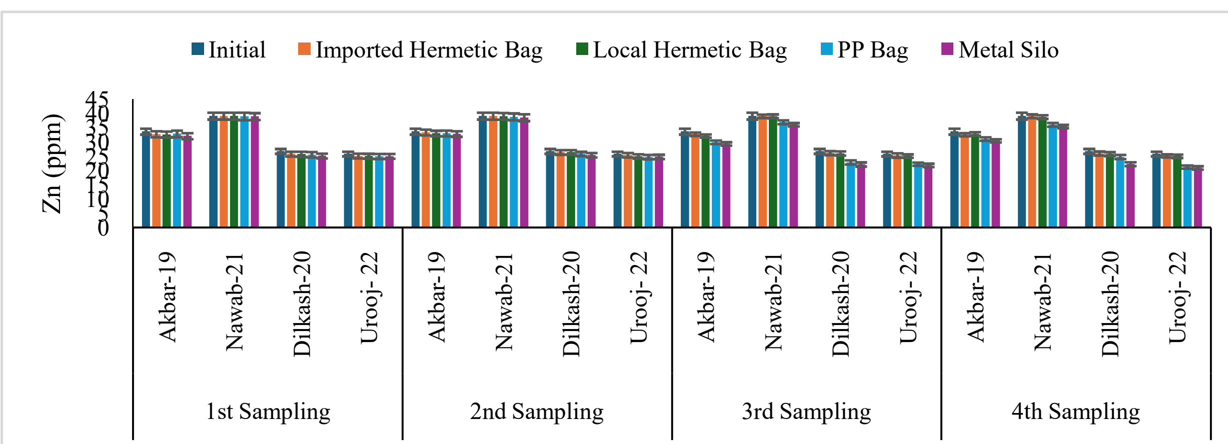


Figure 85 Zn content (ppm) in chapatti prepared from wheat varieties stored in different bags/silos at Multan

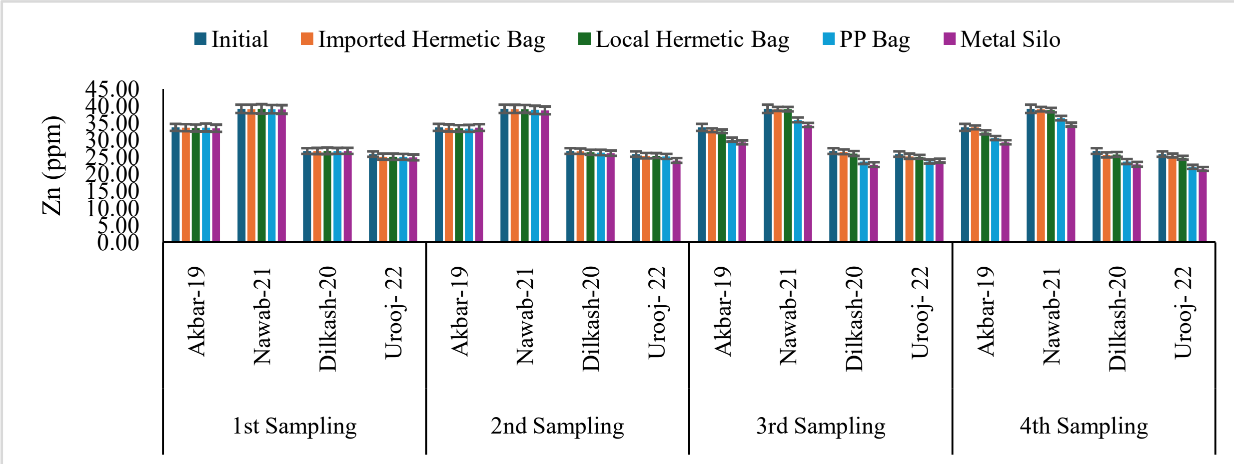


Figure 86 Zn content (ppm) in chapatti prepared from wheat varieties stored in different bags/silos at Khanewal I

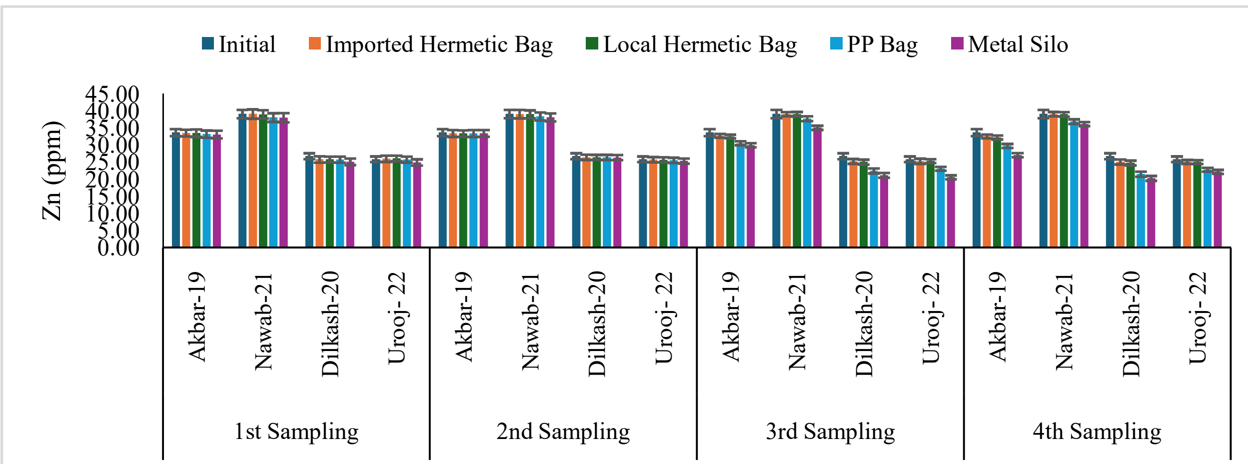


Figure 87 Zn content (ppm) in chapatti prepared from wheat varieties stored in different bags/silos at Khanewal II

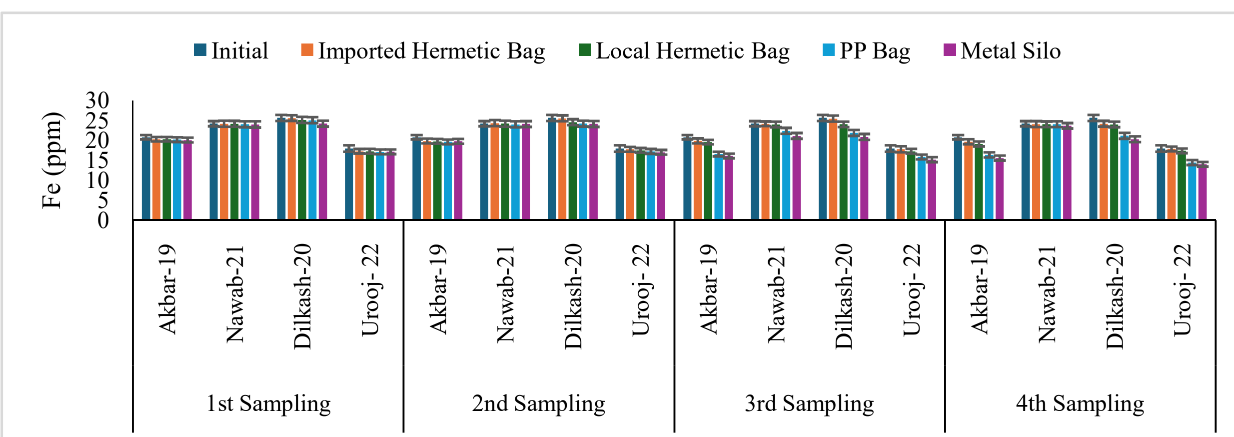


Figure 88 Fe content (ppm) in biscuits prepared from wheat varieties stored in different bags/silos at Jalalpur

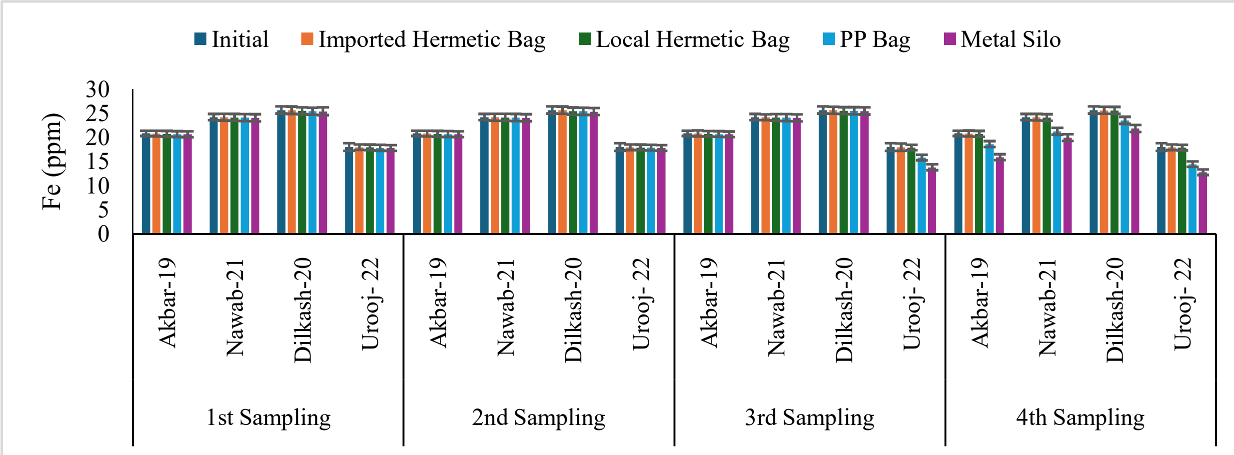


Figure 89 Fe content (ppm) in biscuits prepared from wheat varieties stored in different bags/silos at Multan

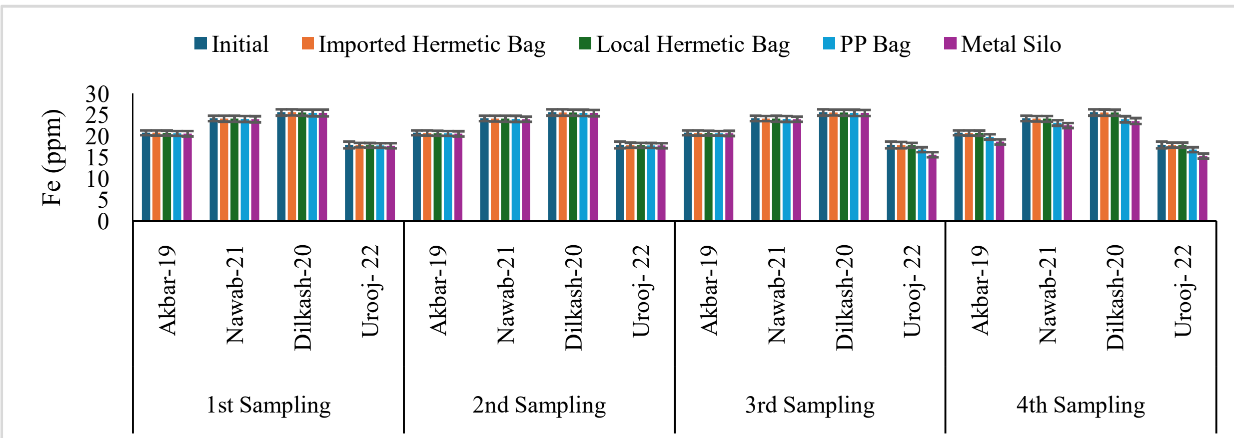


Figure 90 Fe content (ppm) in biscuits prepared from wheat varieties stored in different bags/silos at Khanewal I

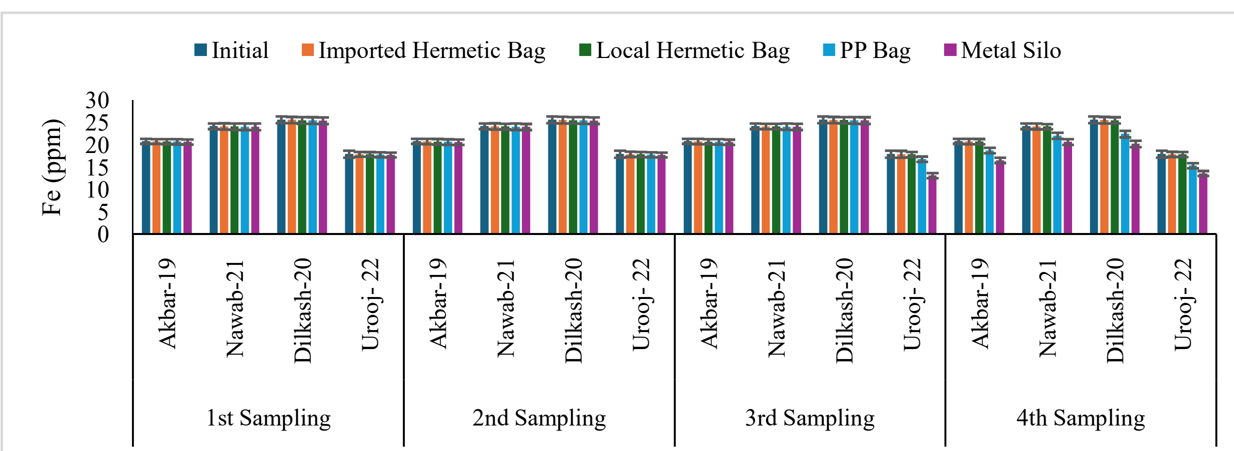


Figure 91 Fe content (ppm) in biscuits prepared from wheat varieties stored in different bags/silos at Khanewal II

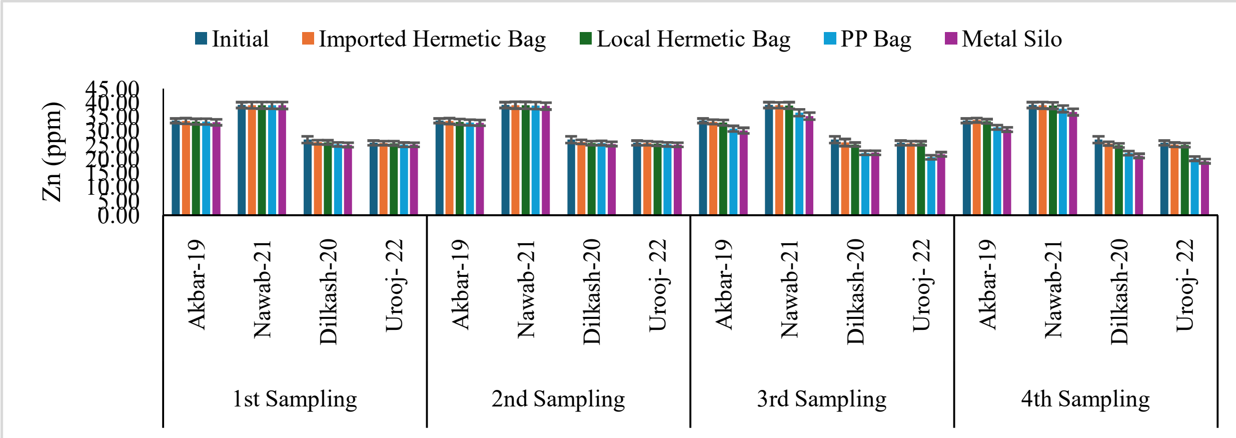


Figure 92 Zn content (ppm) in biscuits prepared from wheat varieties stored in different bags/silos at Jalalpur

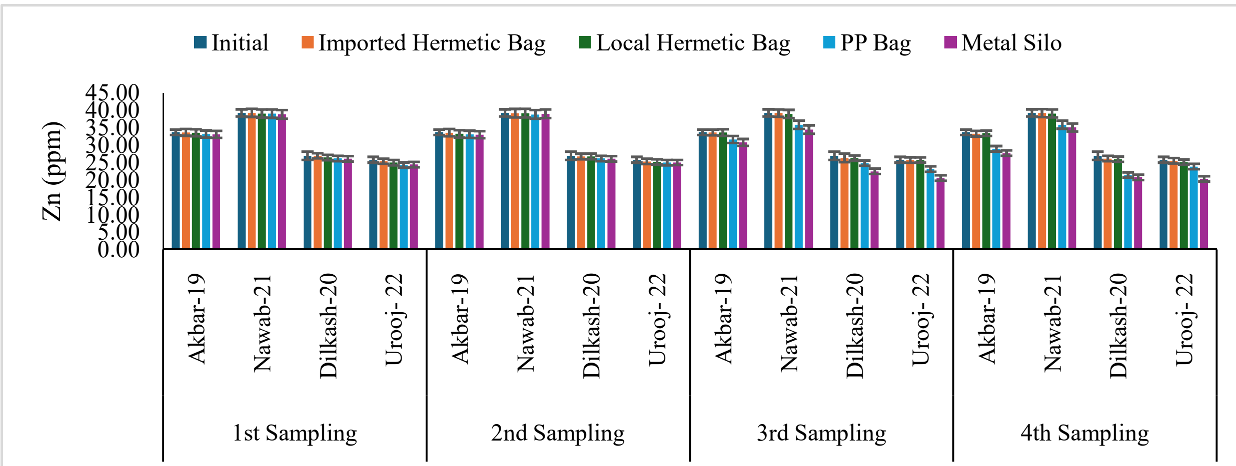


Figure 93 Zn content (ppm) in biscuits prepared from wheat varieties stored in different bags/silos at Multan

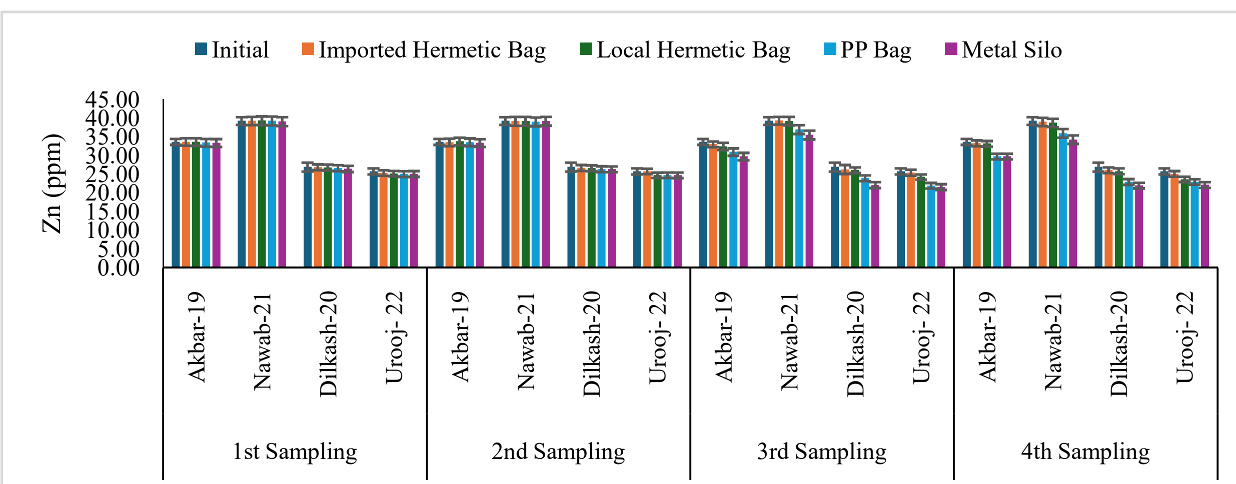


Figure 94 Zn content (ppm) in biscuits prepared from wheat varieties stored in different bags/silos at Khanewal I

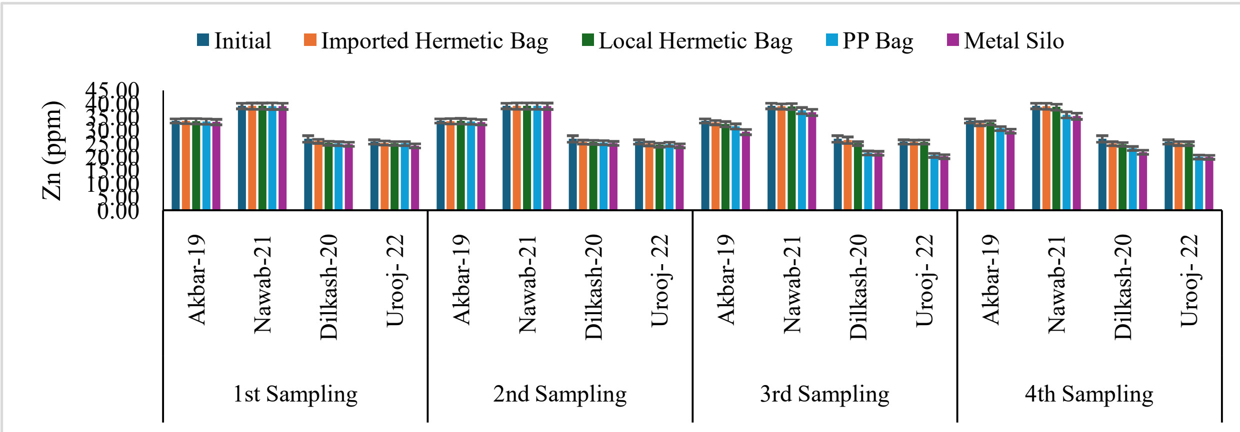


Figure 95 Zn content (ppm) in biscuits prepared from wheat varieties stored in different bags/silos at Khanewal II

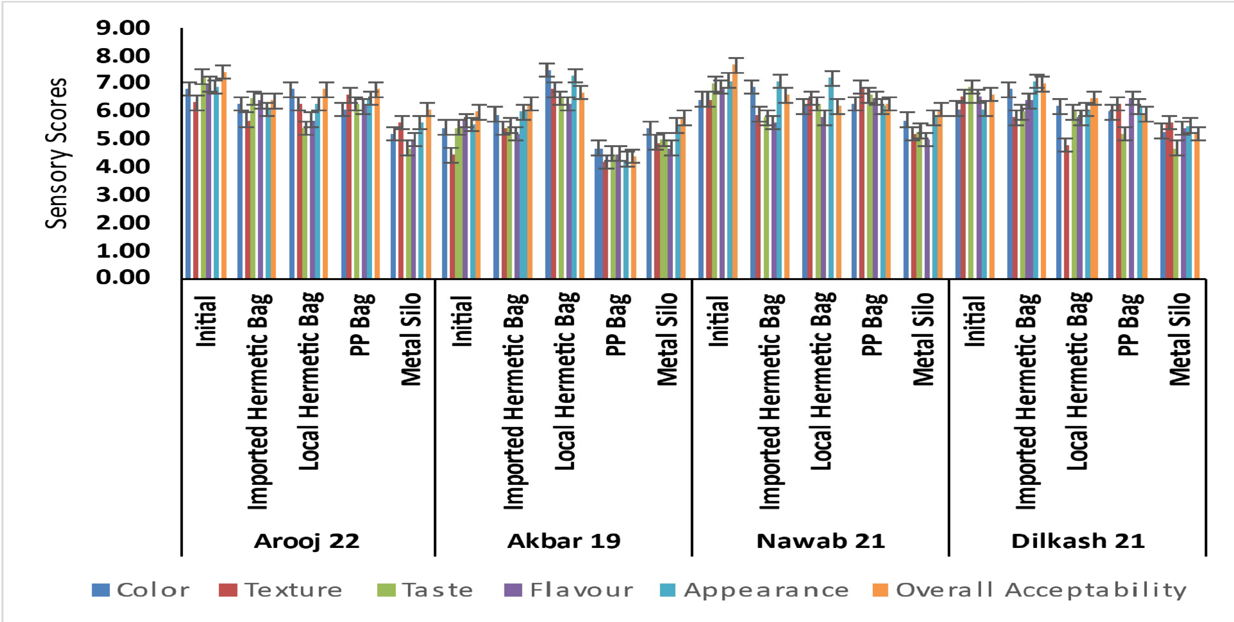


Figure 96 Sensory evaluation of biscuits prepared from wheat varieties stored in different bags/silos

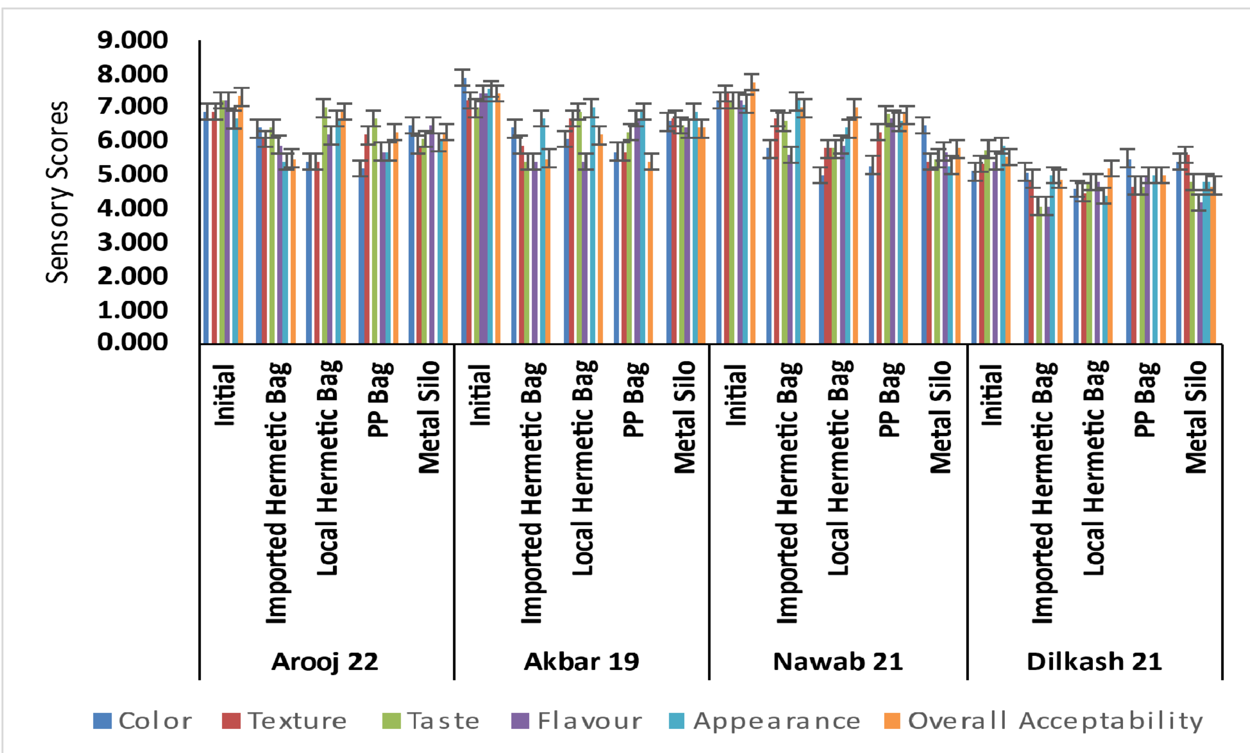


Figure 97 Sensory evaluation of chapatti prepared from wheat varieties stored in different bags/silos

13. Discussion

The present study showed notable decline in nutritional parameters of wheat varieties (normal wheat i.e. Urooj-22 and Dilkash-21 and biofortified Zn wheat i.e. Akbar-19 and Nawab-21) stored in polypropylene (PP) bags and in iron silos for 12 months. The values of nutritional components are in line with the findings of previous study who report that traditional storage caused loss in nutritional composition of wheat varieties as compared to hermetic bags' storage (Melese et al., 2022). Hermetic storage bags are effective at blocking the effects of external humidity fluctuations and insects that's results in less quality loss.

In hermetic bags, oxygen levels reduced significantly because of sealed environment, making it unfavorable for pests and insects and resulted in slowing down grain deterioration and preserving quality. The controlled atmosphere also inhibits the development of pests and molds. While in traditional storage techniques insects and pests get a chance to grow due to the availability of oxygen. It can be concluded that in traditional storage, the insect physically damages the grains and caused loss in nutritional profile of grains (Melese et al., 2022).

In present study the imported and local hermetic bags have significant impact on wheat storage while the conventional storage bags reduce the water absorption capacity and shorten the dough development time, and the dough stability reduced, and this is due to insects that physically damage the wheat grain. The previous study also reveals that the damage seed affects the rheology of flour Dizlek, Ozer (2017).

Similarly, the current study revealed that after 12 months of storage there is no significant difference in chapatti and biscuits prepared from wheat stored in local and imported hermetic bags while significant loss in sensory profile of the chapatti and biscuits was observed after 6-month storage in conventional storage. These results are in line with findings of Katyal et al., (2024) and Mohan, Gupta (2015) who reported that sensory characteristics of product decreased when prepared from wheat affected from insects.

14. Conclusion

- The initial Seed moisture percentage was 9.2% to 10.5% but with the passage of time it increases up to the highest level 12.4% at Jalalpur, 15.1% at Multan, 13.6% at Khanewal-1 and 13.6% at Khanewal location-2 in Nawab-21 wheat variety that were stored in PP bags and iron silos.

- Initially the seed germination ranged between 98.3% to 95.0%, which decreased up to 53.3% at Jalalpur, 60.0% at Multan, 53.6% at Khanewal-1 and 48.3% at Khanewal location-2 stored in PP bags and iron silos while the maximum germination 81.6% was recorded in hermetic bags.

- Electrical conductivity of seed leachates which is inversely related to seed vigor, initially ranged between 26.0-37.0 $\mu S\ cm^{-1}g^{-1}$ but increases up to 69.2 $\mu S\ cm^{-1}g^{-1}$ at Jalalpur, 69.7 $\mu S\ cm^{-1}g^{-1}$ at Multan, 64.5 $\mu S\ cm^{-1}g^{-1}$ at Khanewal Location-1 and 62.9 $\mu S\ cm^{-1}g^{-1}$ at Khanewal location-2 in iron silos and PP bags while minimum changes recorded in imported hermetic bags as well as local hermetic bags.

- The highest damaged grain percentage was recorded at location-1 Khanewal 66.0%, 64.5% at Multan, 60.0% at Khanewal location-2 and 54.5% at Jalalpur location in PP bags and iron silos. Hermetic bags had very minor losses which are non-significant but in case of local hermetic bags only about 3.5% damage in few replicates were recorded.

- The highest weight loss percentage was recorded at Multan 30 %, Jalalpur 31 %, 31% at Khanewal location-1 and 29 % at Khanewal location-2 in iron silos and PP bags. Hermetic bags had very minor losses which are non-significant but in the case of local hermetic bags only about 0.8% weight loss were recorded.

- In the storage period of 1-year only traces of aflatoxins are found ranges from 0.01ppb in local hermetic to 0.08ppb in PP bags and iron silos even though its quantity is non-hazardous and does not pose a direct threat to human health or animal health.

The current study was conducted to check the effect of conventional storage practices and hermetic storage on normal wheat and zinc biofortified wheat (BZW). The study was conducted over three different locations (Khanewal, Multan and Jalalpur) using conventional (Iron silos, polypropylene bags) and hermetic (imported and local hermetic bags) storage conditions to store normal wheat (Urooj and Dilkash) and BZW (Nawab and Akbar) for 12 months. The results indicated that BZW were nutritionally enriched (protein, Zn, and gluten content) over normal wheat varieties. Hermetic storage conditions (local and hermetic) showed better results in preserving the nutritional quality of wheat than conventionally used storage conditions (iron silos and pp bags). Wheat varieties stored in conventional methods were more prone to insect/pest attack due to availability of oxygen and resulted in loss in nutritional quality of wheat varieties and in the products prepared from those wheats. It can be concluded that BZW were more nutritious than normal wheat and hermetic storage conditions (local and imported hermetic bags) are better to preserve the nutritional quality of wheat.

15. References

Afzal, I., Bakhtavar, M. A., Ishfaq, M., Sagheer, M., & Baributsa, D. (2017). Maintaining dryness during storage contributes to higher maize seed quality. Journal of Stored Products Research, 72, 49–53.

American Association of Cereal Chemists. 2000. Approved Methods. St. Paul, MN, USA. Methods 08-01, 30-25, and 46-13. ISBN: 1891127128.

AOAC. 2006. Association of Official Analytical Chemists. Official methods of analysis, 20th ed. Rockville, MD, USA. ISBN: **0935584773**.

Bakhtavar, M. A., Afzal, I., & Basra, S. M. A. (2019b). Moisture adsorption isotherms and quality of seeds stored in conventional packaging materials and hermetic Super Bag. PLoS One, 14(2), e0207569.

Bakhtavar, M. A., Afzal, I., Basra, S. M., & Wahid, A. (2019a). Implementing the 'dry chain'during storage reduces losses and maintains quality of maize grain. Food Security, 11, 345–357.

Baributsa, D., & Concepcion Ignacio, M. C. (2020). Developments in the use of hermetic bags for grain storage.

Bewley, J. D., Bradford, K. J., Hilhorst, H. W., Nonogaki, H., Bewley, J. D., Bradford, K. J., Hilhorst, H. W., & Nonogaki, H. (2013). Germination. Seeds: Physiology of Development, Germination and Dormancy, 3rd Edition, 133–181.

Bradford, K.J., P. Dahal , J. Van Asbrouck, K. Kunusoth, P. Bello, J. Thompson and F. Wu. 2018. The Dry Chain: Reducing postharvest losses and improving food safety in humid climates. Trends Food Sci. Technol. 71:84-93.

Covele, G., Gulube, A., Tivana, L., Ribeiro-Barros, A. I., Carvalho, M. O., Ndayiragije, A., & Nguenha, R. (2020). Effectiveness of hermetic containers in controlling paddy rice (Oryza sativa L.) storage insect pests. Journal of Stored Products Research, 89, 101710.

Dizlek, H., & Özer, M. S. (2017). Effects of sunn pest (*Eurygaster integriceps*) damage ratios on rheological characteristics of wheat flour. Quality Assurance and Safety of Crops & Foods, 9(1), 47-54.

Dizlek, H., & Özer, M. S. (2017). Improvement bread characteristics of high level sunn pest (Eurygaster integriceps) damaged wheat by using transglutaminase and some additives. Journal of cereal science, 77, 90-96.

Food and Agriculture Organization of the United Nations, The state of food and Agriculture: Sustainable Food Systems for Food Security and Nutrition. Available online at: https://www.fao.org/bodies/conf/c2013/en/ ; 2013 [accessed 9 September 2023]

Harrington, J. F. (1973). Packaging seed for storage and shipment.

International Seed Testing Association (ISTA). 2018. International Rules for Seed Testing. ISTA, Bassersdorf, Switzerland. ISBN: 978-0-9954909-2-4.

Katyal, M., Thakur, S., Singh, N., Khatkar, B. S., & Shishodia, S. K. (2024). A review of wheat chapatti: Quality attributes and shelf stability parameters. Food Chemistry Advances, 4, 100736.

Katyal, M., Thakur, S., Singh, N., Khatkar, B. S., & Shishodia, S. K. (2024). A review of wheat chapatti: Quality attributes and shelf stability parameters. Food Chemistry Advances, 4, 100736.

Kuyu, C. G., Tola, Y. B., Mohammed, A., Mengesh, A., & Mpagalile, J. J. (2022). Evaluation of different grain storage technologies against storage insect pests over an extended storage time. Journal of Stored Products Research, 96, 101945.

McDonald, M. B. (2007). Seed moisture and the equilibrium seed moisture content curve. Seed technology, 7-18.

Melese, B., Satheesh, N., Fanta, S. W., & Bishaw, Z. (2022). Effects of storage bags type and storage duration on seed quality and proximate composition of emmer wheat (Triticum dicoccum L.) in Ethiopia. Heliyon, 8(12).

Melese, B., Satheesh, N., Fanta, S. W., & Bishaw, Z. (2022). Effects of storage bags type and storage duration on seed quality and proximate composition of emmer wheat (*Triticum dicoccum* L.) in Ethiopia. Heliyon, 8(12).

MOHAN, D. M., & Gupta, R. K. (2015). Assessment of non-grain parameters in wheat quality under. Journal of Cereal Research, 7(1).

Mohan, D., Tiwari, V., & Gupta, R. K. (2017). Progression in yield and value addition of Indian bread wheat–an analysis. Indian Journal of Genetics and Plant Breeding, 77(01), 16-24.

Strelec, I., Popović, R., Ivanišić, I., Jurković, V., Jurković, Z., Ugarčić-Hardi, Ž., & Sabo, M. (2010). Influence of temperature and relative humidity on grain moisture, germination and vigour of three wheat cultivars during one year storage. Poljoprivreda, 16(2), 20-24.