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Effect of storage conditions on deterioration of rye and canola

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Abstract. *Canada produces about 0.32 million tonnes of rye and 6.9 million tonnes of canola annually. Moisture content and storage temperature are the two major factors that influence the deterioration of grain during storage. The objective of this work was to determine the safe storage period of canola and rye at various moisture and temperature conditions. Canola and rye with different initial moisture contents (10, 12.5, 15, and 17.5% (wb) for rye and 7.5, 10, 12.5 and 15% (wb) for canola) were stored at four different temperatures (10, 20, 30 and 40^oC) for 16 weeks. Germination, moisture content and appearance of visible mould were measured every week and invisible moulds were identified once every four weeks. Moisture content, temperature and storage period had significant effects on germination rate (α=0.05). Germination rate of the 17.5% moisture content rye samples and 15% moisture content canola samples reached 0% during fifth and fourth week, respectively. But it remained above 80% for the samples stored at low moisture and low temperature even during the 16th week. Moisture content of the samples stored at 10^oC did not change significantly. But that of the samples stored at 30^oC reached 5-7% (canola) and 10-13% (rye) during the 16th week and at 40^oC, it decreased to 2-4% (canola) and 5-6% (rye) during the last week of storage. High moisture samples lost moisture with increased storage temperature and time. The visible mould started appearing during the first week of storage in the high moisture samples stored at 40^oC. Appearance of visible mould increased with increasing moisture content and storage temperature. Aspergillus and Penicillium species occurred predominantly in both the grains. Safe storage period decreased with increasing temperature and moisture content.*

Keywords: *Canola, rye, temperature, moisture content, safe storage period.*

Introduction

Canada produces about 320 thousand tonnes of rye (*Secale cerealeare)* and 6880 thousand tonnes of canola (*Brassica napus* L) every year (CWB 2005). Rye has no virtual dormancy which leads to pre-harvest sprouting. Swathing of rye is carried out at 45% moisture content followed by threshing at around 22% moisture content. Therefore, it is necessary to go for early harvesting and proper drying before storage (Weipert 1996). Whereas, swathing of canola is carried out at around 35-40% moisture content. Under good weather conditions the canola seeds can lose 1-2% moisture everyday. Threshing the swathed crop is carried out approximately at 12% moisture content or slightly higher (Mills 2001).

Drying and cooling are the two important post-harvest treatments which immediately follow the harvest. According to Schroth (1996), once the grain is harvested the farmer can have the following options to bring it to the safe storage conditions: The grain can be dried in a heated air dryer and cooled; or ambient air can be used to dry and cool the grain. The choice of the either of the conditioning systems depends on the condition of the grain and the weather pattern. If the harvested grain can be kept for a long enough time at the harvested moisture and temperature conditions without any spoilage, then the farmer can go for ambient air drying, which takes a longer time than the heated-air drying method and can reduce the energy cost**.** So, the period for which the grain can be kept safely at the given condition influences choosing the post-harvest treatment options. Rate of drying and rate of cooling also depend on the available time limit for that particular operation.

Jayas (1995) reported that temperature, moisture, carbon dioxide (CO_2), oxygen (O_2), grain characteristics, microorganisms, insects, mites, rodents, birds, geographical location and granary structure are the important factors to be considered during grain storage. Water content and temperature of the stored grain are considered to be the primary physical factors which influence the deterioration of stored grain (Jayas and White 2003). When the storage temperature and moisture exceeds a particular level, micro flora and mites will multiply and grain will spoil quickly (Sinha 1973, Wallace et al. 1983). Storage conditions have significant effect on important nutritional values of stored rice, wheat and maize. The change was severe at elevated storage temperatures (Zia-Ur-Rehman 2006). Mills (1996) reported that the duration of the intended storage period is also considered to be the most important factor as this influences the maximum moisture level of the stored product that can be tolerated for safe storage. So, moisture content, storage temperature and storage period are the important variables that influence the deterioration process.

The germinability of the grain is considered as the first and foremost factor to assess the viability of the stored product (Pomeranz 1992). If the germination rate decreases below 90% of the initial germination rate, then the storage condition has to be considered as unsafe and protective measures need to be taken (Schroth et al. 1998, Karunakarn et al. 2001). Wallace and Sinha (1962) reported that, germination has no correlation with moisture content, a positive correlation with field fungi; and a negative correlation with temperature and storage fungi.

Measuring the number and kinds of moulds present on the grain will indicate whether an invasion has already occurred. Many researches have tried several methods of quantifying fungi, among which placing a representative sample of seeds on filter paper saturated with sodium chloride and counting the percentage of kernels infected with fungi is the most common and simple method (Wallace and Sinha. 1962; Sinha 1983; Friday et al. 1986). *Alternaria* spp. are the predominant field fungi, whereas *Penicillium* spp. and *Aspergillus* spp. are the predominant storage fungi (Wallace and Sinha 1962; and Christensen and Kaufmann 1969). So, germination rate, change in moisture content, appearance of visible mould and invisible mould are the factors which needs to be monitored continuously to access the stored grain condition. Therefore, the objective of the work was to determine the effect of storage conditions (moisture content, temperature and storage period) on deterioration (germinability and fungal infection) of rye and canola.

Materials and Methods

Fall rye and canola grains were selected for the experimental study and the grain samples were obtained from Agriculture and Agri-Food Canada, Winnipeg, MB. Initial moisture content of the grain samples were determined using the hot air oven method by drying approximately 10 g of grain samples at 130± 2°C for a specified duration (16 h for rye and 4 h for canola) (ASAE 2003) and expressed in percentage, wet mass basis. Grain samples were conditioned to required moisture contents (7.5, 10, 12.5 and 15%; for canola and 10, 12.5, 15 and 17.5% for rye (±0.2% for all the moisture levels)). The temperature range for the safe storage study was based on the possible temperatures the grain would undergo during harvest and storage. According to Muir and Jayas (1997) the average 24 h daily temperature of the Canadian prairies is around 25°C during normal harvesting periods. The grain in the swath has shown higher temperatures than the ambient temperature. Canola seeds maintain about 5°C above the ambient temperature, whereas the cereal grains like wheat maintain about 8°C above the air temperature (Prasad et al. 1978). So, 10, 20, 30 and 40°C temperatures were chosen for this deterioration study. The moisture content of the freshly harvested rye can be anywhere below 20% before it goes for any post harvest treatment. Rye with 14% moisture content is considered as straight grade, whereas 13% moisture content and less is considered safe for storage. Therefore, 10, 12.5, 15 and 17.5 % moisture contents were chosen for rye in this storage study. Similarly, even though 10% moisture content canola seeds are considered as straight grade, 8% moisture content is the safe storage moisture content. So, 7.5, 10, 12.5 and 15% moisture contents were chosen for canola.

Relative humidity (RH) of the grain samples of different moisture contents were maintained using potassium hydroxide (KOH) solutions of different concentrations (Solomon 1951). KOH solutions of densities 1.285, 1.211, 1.147 and 1.108 were used to maintain 60, 75, 85 and 90% RH for 7.5, 10, 12.5 and 15% moisture content canola samples and 10, 12.5, 15 and 17.5% moisture content rye samples respectively.

All the experiments were conducted under controlled environmental conditions. Four environmental chambers (CRELAB, Climatic Research Equipment, WHL3-610M, Winnipeg, MB and CONVIRON, Controlled Environments Limited, Winnipeg, MB) were used to maintain 10, 20, 30 and 40°C temperatures with maximum allowance of ± 2°C.

About 400 ml of KOH solution was taken in a sealed plastic container with perforations on the outer surface above the solution level and placed inside a plastic pail. Two kilograms of conditioned grain were taken in a mesh bag and placed over the KOH-filled container inside the pail, which had a loose lid on the top. Three replications were made for each temperature and moisture combinations for both the grains. The grain in the mesh bag was mixed thoroughly and samples were taken at regular intervals for analysis.

Germination rates were assessed by plating 25 seeds on Whatman no. 3 filter paper in a 9 cm diameter Petri-dish saturated with 5.5 ml of distilled water (Wallace and Sinha 1962). The plates were stacked in a vertical stand and covered with polythene bag to prevent desiccation of filter papers and incubated at 20°C for 4 d then the bags were removed. Exactly on the seventh day the number of germinated seeds was counted.

Moisture contents of the samples were determined every week by the hot air oven method (ASAE 2003). Appearance of visible mould was monitored every week by inspecting the sample visually. Invisible microflora was identified once in four weeks by platting 25 seeds on a Whatman no.3 filter paper in a 9 cm diameter Petri-dish saturated with 5.5 ml of 7.5% aqueous sodium chloride (NaCl) solution (Mills et al. 1978). The plates were stacked in a vertical stand and covered with a polythene bag to prevent desiccation of filter papers and incubated at 25°C. On the fourth day the bag was removed and on the seventh day the seeds that were affected by microflora species were identified using a dissecting microscope.

Results and Discussion

Germination

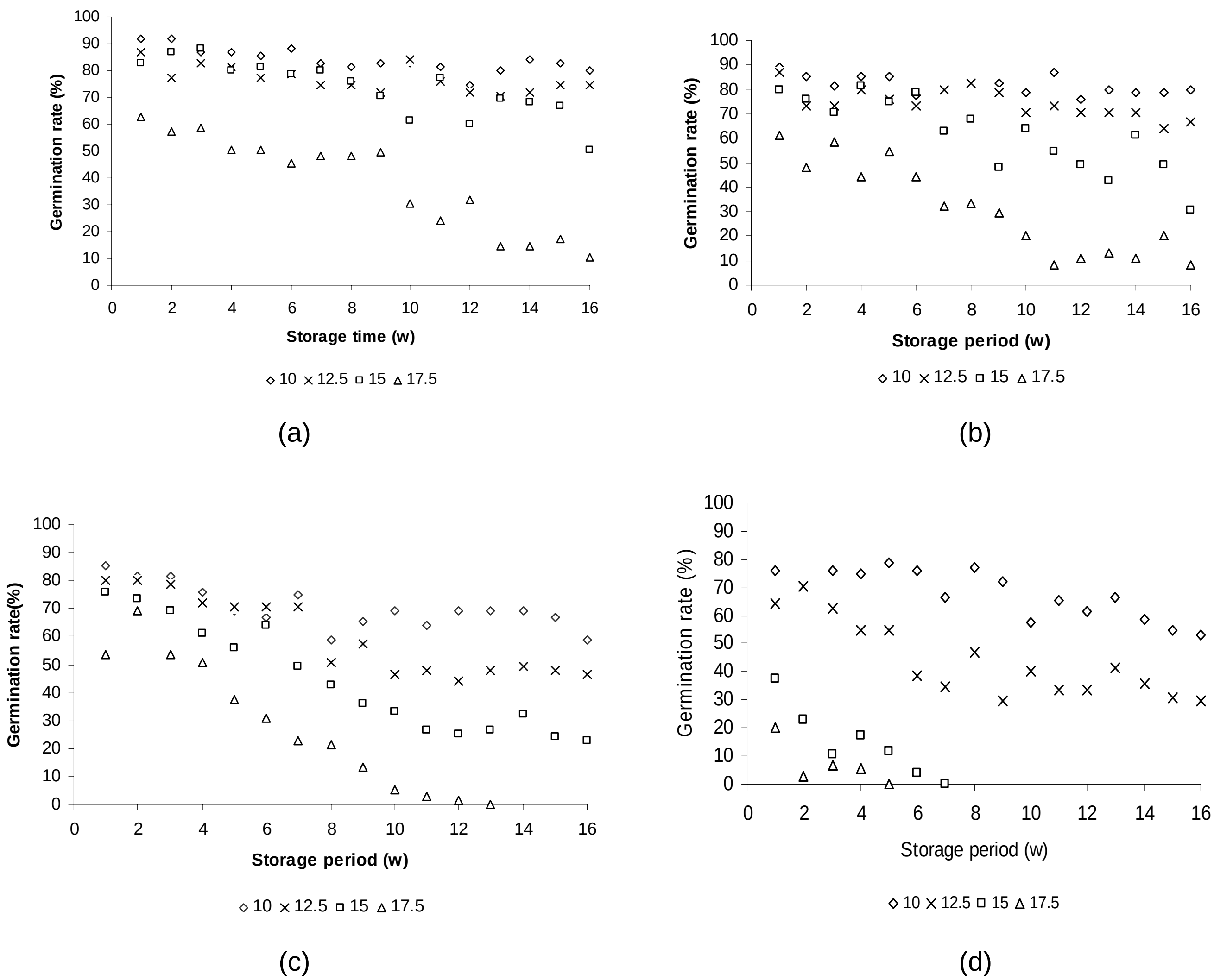
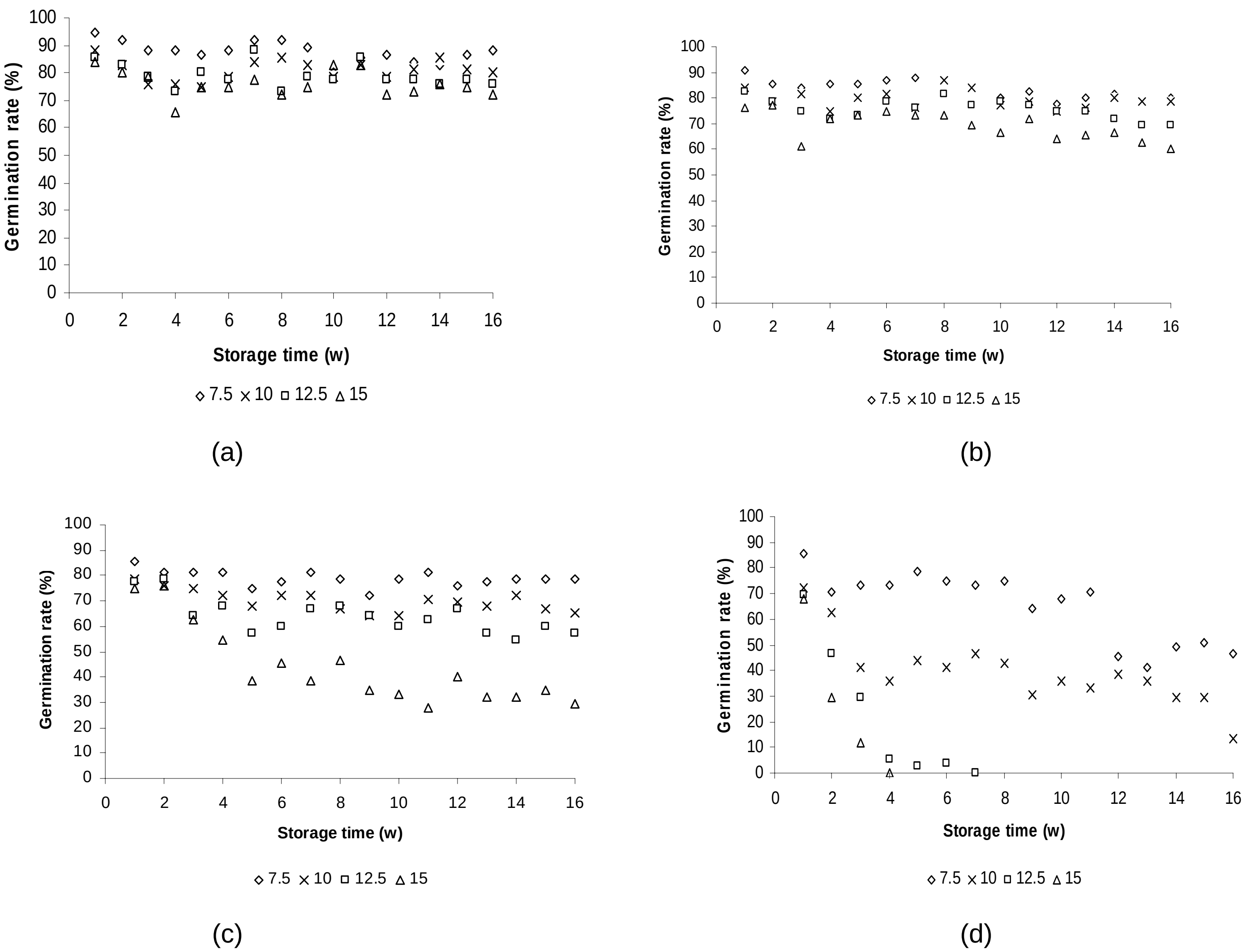


Figure. 1. Changes in germination of rye with respect to moisture content and storage period. (a) at 10°C, (b) at 20°C, (c) at 30°C and (d) at 40°C.

Figure 1 shows the changes in germination rate of rye stored at 10, 20, 30 and 40°C for the period of 16 weeks. Initial germination rate of rye was 92%. It remained above 80% at 10 and 12.5% moisture content samples stored at 10°C. But as the storage temperature increased the germination rate decreased regardless of the moisture content. At 40°C, the germination rate for the 17.5% and 15% moisture content samples reached 0% during 5th and 7th weeks respectively. At 30°C, germination rate of the 17.5% moisture content samples reached 0% during 13th week. Moisture content, storage temperature and storage period had a significant



effect on germination rate of rye (α=0.05).

Figure 2.Changes in germination of canola with respect to moisture content and storage period. (a) at 10°C, (b) at 20°C, (c) at 30°C and (4) at 40°C.

Figure 2 shows the changes in the germination rate of canola stored at 10, 20, 30 and 40°C. Initial germination rate of canola was 96%. All the samples stored at 10°C, had more than 70% germination rate at the end. Low moisture samples (7.5 and 10%) stored at 10°C remained above 80% even during the 16th week of storage. Germination rate of the 12.5 and 15% moisture content samples stored at 40°C reached 0% during 4th and 7th week, respectively. Germination rate of canola was significantly affected by temperature, moisture content and storage period (α=0.05).

Moisture content

Potassium hydroxide solutions failed to maintain the relative humidity constant inside the pails. So the initial moisture content of the stored grain samples could not be maintained throughout the storage study. The moisture content of all the grain samples stored at high temperatures (30 and 40°C) decreased with storage time. Rye samples stored at 10°C, had a slight increase in its initial moisture content over time, whereas moisture content of the 20°C samples remained almost constant throughout the storage period. Rye samples initially at 17.5% moisture content stored at 30°C lost moisture and reached 12.5% by the 16th week. There was not much change in the moisture content of the canola samples stored at 10°C, whereas the samples stored at 20°C dried over time. Canola samples initially at 15% moisture content and stored at 30°C reached 7.2% during the last week of the study. Potassium hydroxide solutions tend to give too low humidity at elevated temperatures (Solomon 1951). This may be the reason for the decrease in moisture content of the samples stored at higher temperatures.

Microflora

For both the grains, mould growth was first noticeable after the germination dropped well below 80% in all the conditions.

Table 1. Time of the first appearance of visible mould (week) and respective germination rate in rye (%)

		Initial moisture content (% wb)			
Temperature (°C)	Replicate	10	12.5	15	17.5
10	a	_	_	_	2, 60
	b	_	_	_	2, 52
	c	_	_	_	2, 60
20	a	_	_	_	1, 60
	b	_	_	_	1, 56
	c	_	_	_	1, 68
30	a	_	9, 56	5, 56	1, 52
	b	_	9, 64	5, 48	1, 52
	c	_	9, 52	5, 64	1, 56
40	a	10, 64	5, 40	1, 36*	1, 16*
	b	10, 48	5, 52	1, 40*	1, 24*
	c	10, 60	5, 72	1, 36*	1, 20*

* Visible mould might have occurred before this time in these cases because of the length of time interval between sampling dates.

Table 1 shows the time of appearance of visible mould (week) and respective germination rate (%) of rye. Visible mould appeared in all the 17.5% moisture content samples irrespective of the storage temperature. But at 40°C, visible mould appeared in the low moisture samples too. If the grain is at 17.5% moisture content and at 10°C, then it has less than a week to do post harvest conditioning. To store rye for long time, the temperature should be below 20°C, and the moisture content should be below 15%.

Table 2. Time of the first appearance of visible mould (week) and respective germination rate in canola (%)

		Initial moisture content (% wb)			
Temperature (°C)	Replicate	7.5	10	12.5	15
10	a	_	_	_	5, 80
	b	_	_	_	5, 72
	c	_	_	_	5, 72
20	a	_	_	15, 76	3, 60
	b	_	_	15, 68	3, 60
	c	_	_	15, 64	3, 64
30	a	_	8, 76	4, 72	1, 76
	b	_	8, 72	4, 72	1, 72
	c	_	8, 52	4, 60	1, 76
40	a	10, 52	2, 60	1, 64	1, 72
	b	10, 76	2, 76	1, 76	1, 60
	c	10, 76	2, 52	1, 68	1, 72

Table 2 represents the time of appearance of visible mould and respective germination rate of canola. Visible mould appeared in all the samples stored at 40°C and all the samples with 15% moisture content. There were no visible moulds even at 30°C with 7.5% moisture content. Canola seeds at 15% moisture content stored at 10°C have around 3 weeks time for drying, whereas, the same moisture canola at 40°C have to be treated in less than a week time. Storage temperature should be below 20°C, and the sample moisture content should be below 10% for canola to have safe storage without any visible mould.

Initially both the grain samples had a high number of seeds infected by *Penicillium* spp. *Aspergillus* and *Penicillium* spp. were predominant in all the samples during the storage study. In rye, at 10 and 20°C, *Penicillium* spp. was dominating during early stages of storage and the number of seeds infected with *A. glaucus* increased over time. *A. candidus* and *Hormodendrum* were present in all the samples. *A.ochraceous* increased with moisture content and storage period. At 30 and 40°C, *A. glaucus* was the dominating species. The number of seeds infected with *A. ochraceous* increased with moisture content and storage period. *A. candidus* and *A. wentii* were the other two common *Aspergillus* spp. present in the samples.

Penicillium spp. were dominating throughout the entire storage period in all the canola samples. At 10°C, *A. glaucus* was present in the low moisture samples and there was no *A. ochraceous* in any of the samples. Few seeds in the high moisture samples had *Fusarium*. At 20°C, number of seeds infected with *A. glaucus* increased with storage period. *A. candidus* and *Hormodendrum* were present in all the samples throughout the entire storage but few in numbers. *Fusarium* and *A. wentii* were present only in early stages. At 30°C also *Fusarium* was found in early stages of storage. The number of seeds with *A. glaucus* increased with respect to storage time. At 40^{o}C, *A. glaucus* was predominant next to *Penicillium* in all the samples followed by *A. candidus*. 15% moisture content samples had the highest number of seeds infected with *A. ochraceous*. *Fusarium, Hormodendrum* and *A. wentii* were present only during the early stages of storage.

Conclusion

Germination of both the grains were significantly affected by moisture content, temperature and storage period (α=0.05). Germination rate decreased with increased moisture content, temperature and storage period. Initial moisture contents of all the samples could not be maintained throughout the entire storage period. Moisture content of both the grain samples stored at 10^{o}C increased slightly over time. But that of the samples at 30 and 40^{o}C decreased with respect to time. Initially both the grain samples had a large number of seeds infected with *Penicillium*. It was the dominating spp. in all the samples throughout the storage study. *A. glaucus* increased in infection levels with respect to storage period. *A. ochraceous* was present in high moisture samples during later stages of storage. Rye can be stored safely at moisture contents below 12.5% and at temperatures below 20^{o}C for a long time. If the moisture content is above 15% and the temperature is above 20^{o}C, then the grain has to be treated within a week to prevent spoilage. Similarly, moisture contents of less than 10% and storage temperature of 20^{o}C or less are the safe storage conditions for canola. Visible mould appeared in the samples only after the germination decreased well below 80%. Even though all the samples had invisible moulds, visible mould was noticeable only in the samples with greater than 15% (rye) and 10% (canola) moisture contents and stored above 20^{o}C.

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