# Effects of intercropping wheat and rye on yield and protein content of wheat.

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**Abstract**

Climate change and growing population bring the need to find other method of producing grains in order to meet the need for global population. Intercropping has proved to be an efficient method of crop production as often different crops do not have the same nutrient uptake. Intercropping promotes nutrient balance. In this study, wheat and rye were intercropped to determine if intercropping negatively impacted wheat yield or protein content. Data were analyzed by ANOVA and no significant differences were found between wheat varieties grown in monoculture and polyculture.

**Introduction**

Intercropping can improve resource use efficiency (Gliessman, 1998). Mixtures of grains, particularly wheat and rye, are called 'maslin,' and have been grown in for at least 3,000 years (McAlvay et al., 2022). Growing maslin enhanced yield stability in years where one of the grains did not perform well due to nutrient deficiency, poor weather conditions, or lack of seed vigour. Cultivar mixtures also reduce the spread of plant pathogens (McAlvay et al., 2022).

Triticeae is amongst the most important groups of crop plants due to its wide utilization for food, feed, and beverages. It consists of rye, wheat, triticale, and barley. Among them, wheat (*Triticum aestivum* L.) feeds more than half of the global population (Rehman et al., 2020; Rehman et al., 2020; Usman et al., 2023; Atta et al., 2023). Many traditional cropping systems imitate unmanaged ecosystems in structure and/or diversity (Winter et al., 2020), but maslins—mixtures of cereal species such as wheat, barley, rye, or oats—are comparatively little studied (McAlvay et al.,2022). Wheat, rye, barley, and other small grains yields are expected to decline in the face of climate change unless farmer practices change (Challinor et al. 2014; Wang et al. 2018; Leng and Hall 2019; McAlvay et al.,2022). In a mixed culture crop production system, one or more crop is added to a cropping system and, as a general rule of ecological principle, diverse ecosystems are expected to be more resilient and sustainable in the long term (Gliessman, 1998).

For thousands of years farmers have been intercropping crop varieties and species to mitigate weather-related losses and to manage risk (Maezumi et al. 2018; Maitra et al. 2021). intercropping within the same botanical family (e.g. wheat and barley) is less well studied (Woldeamlak et al. 2008a). Intercropping varieties of the same botanical species offers unique benefits and trade-offs that are less well known.

Field trials with certain cereal mixtures have shown promising potential for enhanced yield advantage (Prasad et al. 1988; Woldeamlak et al. 2008a), yield stability (Woldeamlak et al. 2008b), weed resistance (O'Donovan et al. 1985; Cousens 1996; Kaut et al. 2008), and pest and pathogen resistance (Clark 1980).

The present experiment is based on a study performed by the university of Manitoba (Citation?). Cultivar Mixtures, Cover Crops, and Intercropping with Organic Spring Wheat. This choice was motivated by the UN sustainable goals for eradicating famine in the world as most of the world population consume wheat product and in recent years in different parts of the world yields have either been lost or been low due to various climatic conditions.

The aims of this study are to evaluate whether a wheat and rye intercropping system affects (i) wheat yield, (ii) rye yield, or (iii) wheat protein content relative to wheat and rye monocultures.

**Method**

This experiment was conducted at the KPU Farm on Garden City Lands, in Richmond, BC located 1 meter above sea level (49.17° N, -123.12° W). The climate is temperate west coast with an average temperature of 10°C and average annual precipitation of 1.112.6 m (Tourism Richmond 2020, City of Richmond 2018). The site has three different layers of soil with peat at the very bottom, followed by a 70 cm of mineral soil (sandy clay loam or clay) and 5 cm of organic topsoil at the Surface, due to heavy amendments with compost and manure and other organic matter.

The experiment was set up in a randomized complete block design with four replicates (Figure 1). Each plot was 2 x 2 m and there were five treatments:

1. Rye (cv. Gazelle) monoculture;
2. Wheat (cv. Kamut) monoculture;
3. Wheat (cv. Red fife) monoculture;
4. Wheat (cv. Kamut) and rye polyculture; and
5. Wheat (cv. Red fife) and rye polyculture.

All seed was sourced from Storehouse Foods (Lacombe, AB). The grain was sown at a rate of 150 seeds per $m^2$ on June 29, 2023, using a Jang seeder. Seed was sown in 24 rows of 24 seeds, with in-row spacing of 8 cm. In polyculture plots the seeding rate was 75 seeds per $m^2$ for each crop so that the total seed density was the same in all plots. Polycultures plots were sown in alternate rows of wheat and rye. After seeding, all plots were layered with 1 cm of compost mulch to prevent weed germination. All plots were irrigated daily using overhead sprinkles for the first 6 weeks, then irrigation was decreased gradually over the next 6 weeks to zero. The


Figure 1. Randomized complete block design detailing the plot layout of the study. Plots are blocked by column in this figure, but all plots were arranged in a single line at the field site.

Harvest

The wheat was harvested using a hand sickle 118 days after seeding on October 25$^{th}$ 2023. A sample was collected from 1 $m^2$ in the centre of each plot. The harvested stalks were air dried for 14 days before threshing with a string trimmer in a bucket. The threshed material was cleaned using a series of screens prior to winnowing in an air separator (Type 4604.1, Seed Processing, Holland).

Data collection

Dry weight of grain was recorded for each sample. A 25 g subsample from each wheat plot was tested for protein content using the protein combustion method (Dumas AOAC 990.03, SGS lab, Burnaby, BC).

Statistical analysis

Treatment effects on wheat yield and protein content were analysed by analysis of variance (ANOVA) in jamovi (version2.3). A critical value of $\alpha = 0.05$ was maintained throughout. Means were separated by Tukey's test if ANOVA detected any significant effect. A Pearson correlation coefficient was calculated to test for any relationship between wheat yield and protein content.

**Results**

Most rye did not set seed, so only wheat yield was collected.

Monocultures had a higher wheat yield than wheat/rye mixtures ($F_{1,9} = 21.85$, $p < 0.001$). Red fife yield was higher than kamut ($F_{1,9} = 9.42$, $p = 0.013$). No significant interaction was detected between cropping system and wheat variety.

Wheat yield differed between treatments (Table 2, Figure 2). The mean yield of kamut and red fife was 156.7 g and 203.8 g, respectively, in a monoculture and 81.4 g and 131.3 g, respectively, in polyculture (Table 2).

Table 2. Wheat yield and protein content mean, standard deviation, and standard error by treatment.

| | treatments | N | Mean | SD | SE |
|---|---|---|---|---|---|
| Wheat yield (g/m2) | kamut | 4 | 156.7 | 47.085 | 23.543 |
| | redfife | 4 | 203.8 | 28.304 | 14.152 |
| | kamut/rye | 4 | 81.4 | 27.183 | 13.591 |
| | redfife/rye | 4 | 131.3 | 34.795 | 17.398 |
| Protein (%) | kamut | 4 | 10.9 | 0.379 | 0.189 |
| | redfife | 4 | 10.6 | 0.993 | 0.497 |
| | kamut/rye | 4 | 10.9 | 0.862 | 0.431 |
| | redfife/rye | 4 | 10.8 | 1.192 | 0.596 |

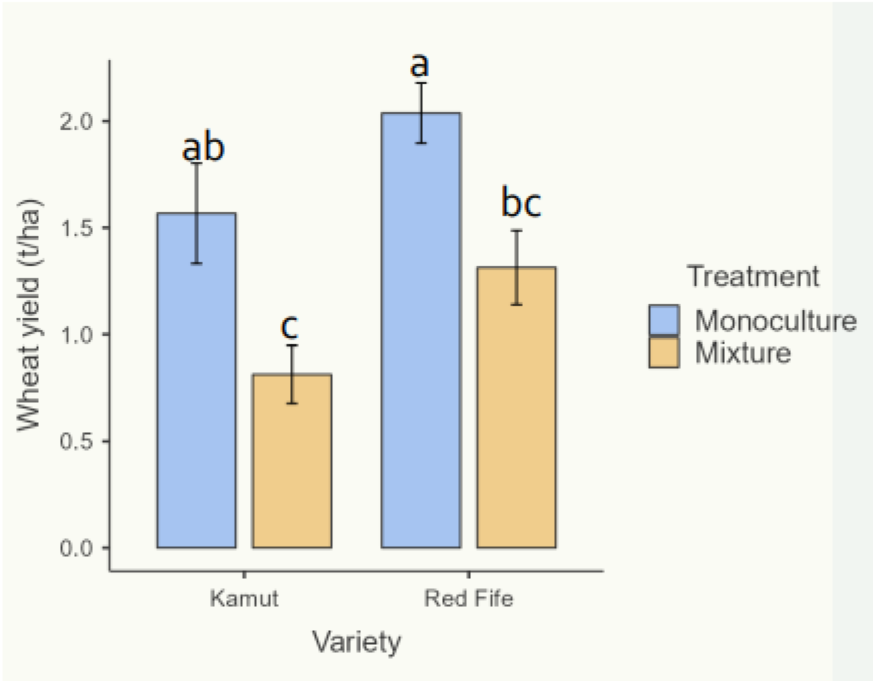


Figure 2. Yield of 'Kamut' and 'Red Fife' wheat varieties in monocultures and 1:1 mixtures with 'Gazelle' rye. Error bars denote standard error. Means labelled with the same letter do not differ significantly (Tukey test, $\alpha = 0.05$)

## Protein content

The protein content ranged from 10.6% to 10.9% and did not differ significantly between treatments (Fig. 3). No correlation was detected between wheat yield and protein content (Fig. 4).

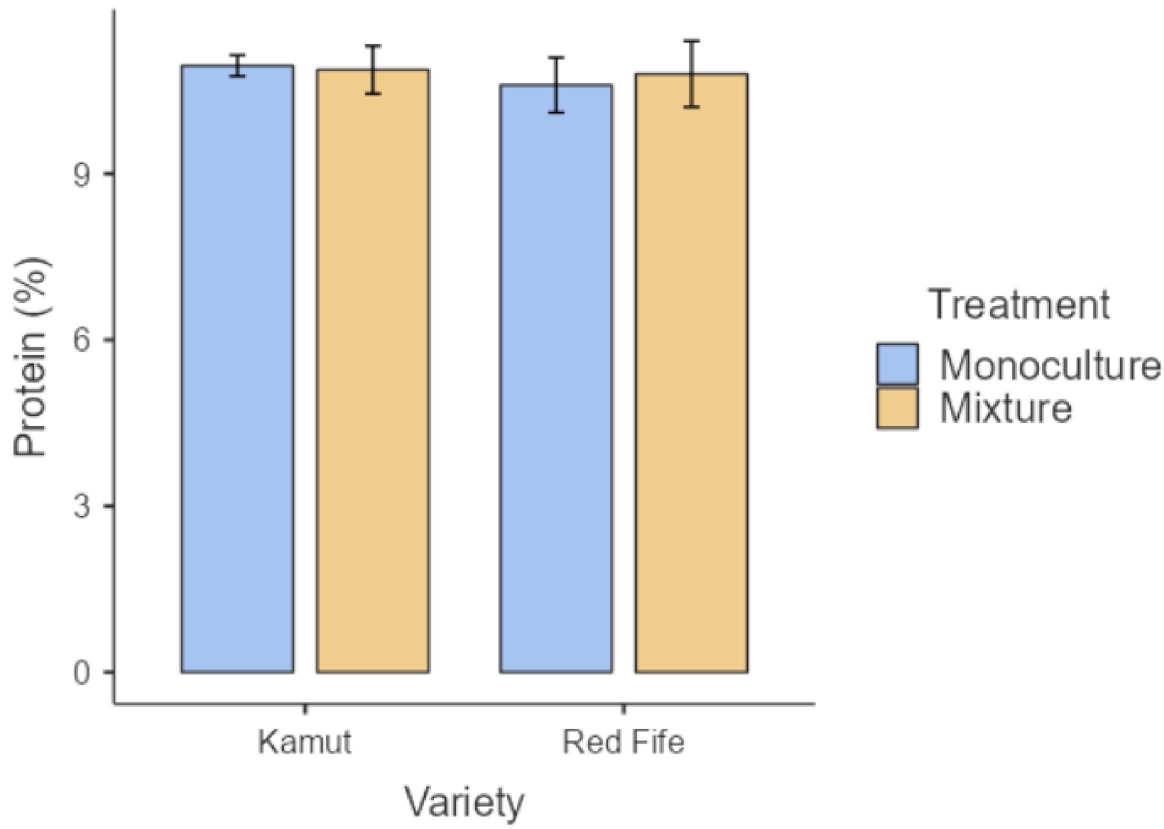


Figure 3. Protein content in ‘Kamut’ and ‘Red Fife’ wheat varieties in monocultures and 1:1 mixtures with ‘Gazelle’ rye. Error bars denote standard error

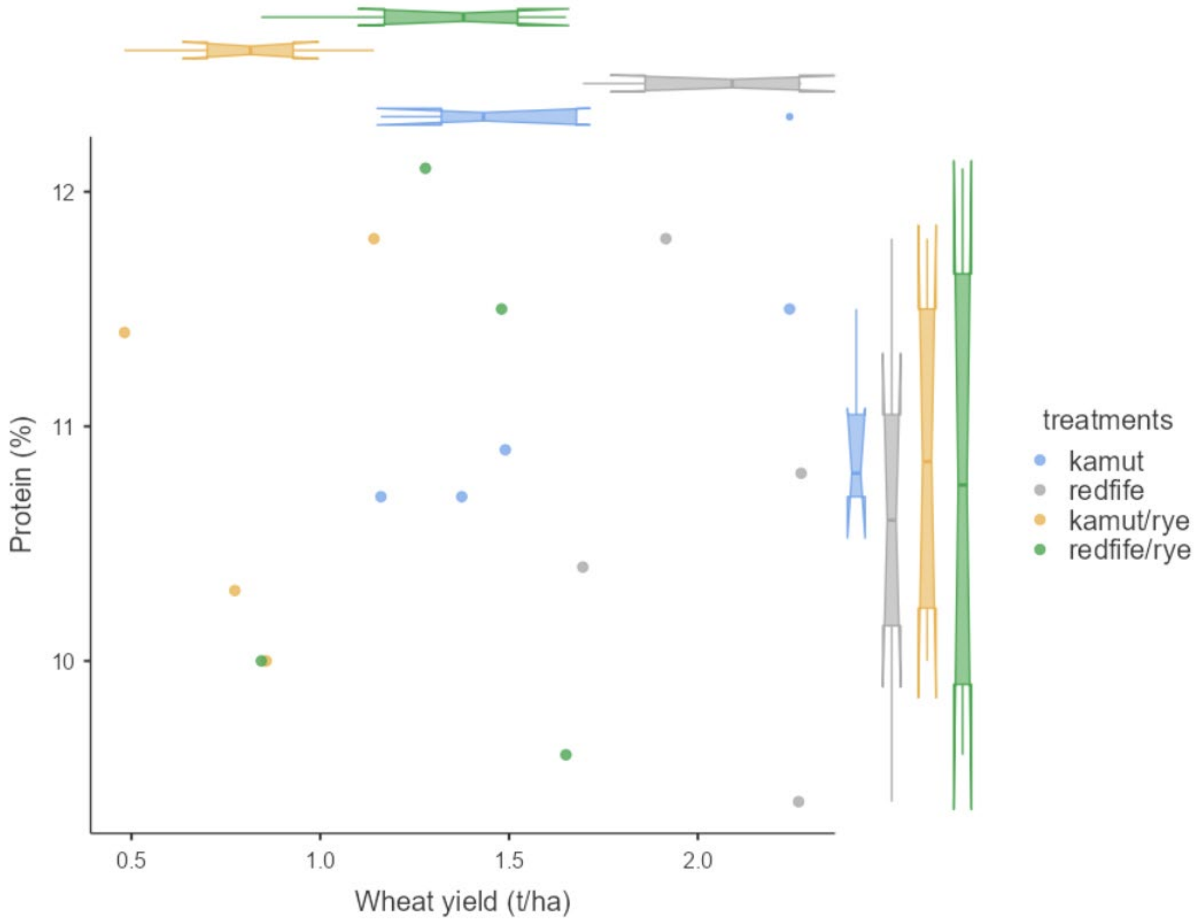


Figure 4. Scatterplot showing wheat yield against protein content by treatment. Marginal boxplots show treatment medians, quartiles, and range.

**Discussion**

The lack of rye seed set was attributed to declining day length over the course of the study. The Gazelle variety of rye has been bred for spring seeding and summer harvest, but may require growth before the summer equinox. Some rye did produce seed in the monoculture plots but this was not sufficient to measure yield.

The study was first seeded at the beginning of June but severe weed pressure forced crop termination and re-seeding at the end of June. A seeding rate of 300 seeds per m$^2$ was originally proposed to enable the crop to out-compete weeds, but the Jang seeder did not allow such a high seeding density. Future studies should use seed broadcasting at 300 seeds per m$^2$ instead of seeding in rows with the Jang seeder.

Seeding in rows was intended to facilitate separation of the different grain types at harvest. The concern with broadcasting is that a mixed harvest does not allow conventional flour processing because maslin flour is not a shelf stable product compared to pure wheat flour. Mechanical harvest and separation of grains is challenging in polycultures.

Wheat yield in polyculture was expected to be 50% of the monoculture yield because the wheat seeding rate was cut in half in the polycultures. The expected yield reduction was observed for Kamut, but the Red Fife yield only fell by 25% in polyculture. Red Fife was bred in Canada, and may be better adapted to Canadian conditions, whereas Kamut comes from Khorasan in Iran (Citation?).

Wheat protein content was expected to be higher in polyculture than monoculture because reduced wheat density in polyculture should have made more nitrogen available to the wheat. The lack of rye seed set should have further reduced competition nitrogen in the polyculture plots. Contrary to expectation, protein content did not differ between treatments (Table 2, Figure 3).

Other studies have shown that protein content is negatively correlated with seeding rate and wheat yield (Citation?). We found no such correlation (Figure 4). Although wheat seeding rate differed between monoculture and polyculture plots, total seeding rate was held constant.

This study was inspired by an old bakers' tale that in early medieval times wheat and rye were grown together in mixtures to ensure a harvest as the yield of each grain varied from year to year. Future studies are needed over multiple years with different growing conditions to determine whether maslin mixtures actually promote yield stability.

Despite a good climate for grain production in southwestern BC the high cost of land would not allow a grain farm to be sustainable. There is little demand for mixed grains compared to white flour. Mixed grains are a niche market and require a lot of skill and knowledge to use. Some studies show that Kamut in high quantities can be toxic to humans (Citation?).

**Conclusion**

The failure of rye in this study demonstrated a benefit of intercropping, in that wheat could still be harvested from the polyculture plots. If one crop fails in a mixture there is a backup crop to provide some income. This insurance come at the cost of a more complicated management system and a reduced wheat yield.

The Red Fife variety of wheat performed better than the Kamut variety, perhaps because it was bred for Canadian conditions.

Protein content did not vary between varieties or between production systems, and was not related to wheat yield, suggesting that nitrogen was not a limiting factor in this trial.

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