Yield Effect of Flax (*Linum usitatissimum)* and Chickpea (*Cicer arietinum)* Intercropping

By
Moira Tarry

Kwantlen Polytechnic University

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Advisor: Michael Bomford
Department of Sustainable Agriculture and Food Systems

Abstract

There is a niche market opportunity in British Columbian agriculture to produce sustainable linen fiber without compromising food security; this experiment explored benefits and challenges of intercropping kabuli chickpeas (*Cicer arietinum)* with common dual purpose flax (*Linum usitatissimum)*. Yield of unprocessed linen fiber, flaxseed, and chickpeas was calculated to compare monocrops and intercrops of these two species. Data was compared and analyzed using both the land equivalence ratio and the relative land output to determine whether monocrops or intercrops of these two species have greater land use efficiencies. Data was analyzed using the land equivalence ratio and the relative land output. Results using the LER indicated that the mixtures did not improve land use efficiency compared to the monocultures. However, results from the RLO indicated that the land use efficiency is greater in mixtures than in monocultures.

Introduction

Global fashion and textile industries pose grave social and environmental threats, from highly underpaid workers in dangerous conditions, to pollution of waterways and over usage of resources (Cai and Choi 2020). As individuals grow more concerned about the effects their habits may have on the environment, there is increasing demand for sustainable fabric (Cai and Choi 2020). There is a niche market opportunity in organic British Columbian agriculture to explore production of fibers for textiles and apparel. By using a dual purpose flax variety in this study, there was a means for measuring linen fiber yield and flax seed, in grams/m^2.

Flax

The Latin name for flax, *Linum usitatissimum,* means "most useful thread" (MacFadyen 2018). It has a long history as a domesticated crop, perhaps dating as far back as 10,000 years ago (Liiv et al 2017). It can be found in archaeological excavations in the form of seed, oil, pollen, textiles, and much more. It can safely be said that linen is a long lasting fiber well worth its extensive labour inputs. It is assumed the earliest domestic flax originates from the Fertile Crescent (now Syria, Lebanon, Israel, Egypt, Turkey, and other countries within this region) (Karg 2011).

Flax produces two important crops which make up for almost the entire biomass of the plant. The flax seeds (also known as linseed) are 36-40% oil, and are rich in dietary fiber, antioxidants, protein, and omega-3 fatty acids (Sargi et al 2013). The oil became mass produced when ready mixed paint became widely available in the late 1800's, which boomed the processing and supply of linoleum and various varnishes, being a key ingredient in all of these products, and still is today. (MacFadyen 2018).

The fibrous stalk of flax (linen) is valued for cordage, clothing, thread, and furniture upholstery including for use in carpets, and even historically for the fabrication of sails (MacFadyen 2018).

Flax stalks must be processed extensively before they may truly be called linen. The first and most crucial step is called *retting.* This is the process of rotting away the woody stem to reveal fibers throughout the plant. There are two ways to ret flax, each with its own advantages

and disadvantages. The first is dew (or field) retting; this can be done by spreading out a layer of harvested flax stems and allowing dew to collect on the stems. This method takes the longer of the two at about four weeks depending on the climate, but appears to have fewer environmental repercussions than water retting (MacFadyen 2018). The second method of retting is water retting, which is to submerge entire bundles of flax stalks into water and allow it to steep for about one week. Historically this would take place in rivers, lakes, ponds, and dugouts called "retting pits," (Liiv et al 2017). The process of retting in natural bodies of water without proper water treatment can lead to hypertrophic ecosystems. There is evidence of this in many lakes throughout Estonia, where water retting flax has been banned since the 1950's, which are still being observed to have phenomenal seasonal ecological occurrences. Traces of flax pollen and flax fossils can still be found in lake sediments throughout Estonian Linajärv (linen lakes) (Liiv et al 2017).

Chickpea

Cicer arietinum is an annual legume valued in intercropping mixes and as a cover crop due to its capacity for atmospheric nitrogen fixation, and as a food crop. It is rich in fiber, protein, vitamins, and minerals. It has been in cultivation for thousands of years and is a promising crop in a changing climate, due to its drought tolerance and ability to withstand both cool and hot weather conditions (Tuba et al. 2022). Kabuli chickpeas have large beige or cream coloured seeds, compared to their counterpart desi chickpeas which are small and dark. They produce two seeds per pod (although they may occasionally produce as few as one or as many as three) which presents a yield advantage for this variety. Chickpeas have an extensive economic footprint, having been cultivated over 17.8 million hectares globally in 2018. Desi

chickpeas are more widely grown than kabuli, making up for 80-85% of chickpeas in production, despite having smaller seeds with fewer to a pod. The varieties are further differentiated by region of production. Desi are commonly produced in East Africa, South Asia, and in Australia, whereas Kabuli are more commonplace in production regions such as the Mediterranean, Eastern Asia, and the Near East, such as Turkey, the Arabian Peninsula, and Israel. Due to the larger size of the kabuli chickpea, it is grown widely by commercial farmers to fetch a higher price than desi chickpeas (Kivrak et al, 2020). There has been a great deal of recent research in chickpea breeding to improve size and to increase the amount of seeds per pod.

Intercropping

There are several different ways to intercrop, each with its own definition, but in essence to intercrop is to grow two or more crops together in the same space. In intercropping systems, chickpeas are often paired with grasses such as wheat or oats; the chickpea fixes nitrogen in the soil and ideally supplies nitrogen for its companion, while the companion puts on biomass (Mohler and Johnson 2009). Though flax is a dicot, it is often compared to and grown like a tall grass since it may grow tall and can be densely planted, and similar harvest methods are employed for flaxseed and wheat (MacFadyen 2018).

An intercropping study by Ahlawat and Gangaiah (2010) between chickpeas and flax was conducted in India. Control plots were 100% chickpeas and treatment plots were chickpeas and flax in a 2:1 ratio. At the end of the study there was a significantly higher chickpea seed yield in the intercropping plots than in the sole plots. Although they didn't have a control for the flaxseeds, they discovered the yield of flaxseed to be greater than they expected due to higher

branching from a looser-than-normal planting density. The results of the study by Ahlawat and Gangaiah (2010) are similar to those in the alternate hypothesis for this study, however this study had a larger amount of focus on flax for both linen and flaxseed, as opposed to being a means for observing specific chickpea responses only.

Objectives

Sustainable textile production is growing in demand but there is minimal production in Southwestern British Columbia. This presents a niche market opportunity for small scale organic farmers in the region. This study focused on two crops: Common flax, with a focus on both the production of linen fiber and the production of flaxseed, and Kabuli organic chickpea. The objective of the study was to observe yield responses of each species as monocrops and as intercrops to determine whether the monocropping system or intercropping system would result in a greater land use efficiency. Outcomes of this research will allow farmers to assess whether it is a practical option for them to incorporate flax in production of legumes. The hypothesis is that the intercropping system will increase the yield of flaxseed, linen fiber and chickpeas, in grams/m^2 compared to the yield from monocrops.

Methods

This intercropping study was conducted using two certified organic seed varieties; Common Flax Organic and Kabuli Organic chickpea sourced from West Coast Seeds. These two

are suitable companions for an intercropping system since they have close dates to maturity and favour similar growing conditions. They were planted using a randomized complete block design generated by the statistical platform *Jamovi.*

There were fifteen 2m² plots. Treatments were chickpea monoculture, flax monoculture, and chickpea/flax mixture. Flax monocrops madee up five plots, chickpea monocrops made up five plots, and intercrops of flax and chickpeas made up five plots. Walkways were approximately 1 meter wide between plots. Flax plots were sown with 800 seeds (a density of 400 seeds/m²), chickpea plots were sown with 80 seeds (40 seeds/m²) and intercropped plots had 400 flax seeds (200/m²) and 40 chickpea seeds (20/m²).

FIgure 1:. Randomized complete block design detailing the plot layout of the study.

Dependent variables were the weight of dried chickpea seeds, the weight of flax seeds, and the weight of dried flax stalks. Crops were sown on May 6th, 2022. Flax was harvested on August 5th, and chickpeas were harvested on August 15th.

After planting, there were 90-100 days before flax and chickpea harvest. Chickpeas were harvested and assessed by plucking the pods off of each plant, shelling them, drying them, and weighing them. Flax was pulled from the ground by hand and tied into bundles to dry for ten days. Seed heads were removed using a handmade rippler and shelled and weighed, and then the separate stalks were weighed. All measurements of weight were recorded in pounds per meter squared, converted into grams per meter squared, and recorded to the first decimal place.

Data was analyzed using the land equivalence ratio (LER) and the relative land output (RLO.) These equations determine land use efficiency and can be interpreted the same way, though they are executed differently.

The LER is a sum of ratios which has been popularly used since 1965. For the context of this experiment, it was calculated by dividing the yield of the flax mixture by the yield of the flax monoculture, plus the yield of the chickpea mixture divided by the yield of the chickpea monoculture (Martin-Guay et al, 2018.)

The RLO was more recently developed in 1997 and is less commonly employed. It is a ratio of sums. For the context of this experiment, it was calculated by dividing the entire mixture output (yield of mixed flax and mixed chickpeas) by the entire monoculture output (yield of sole flax and sole chickpeas.) For this experiment the mixed plot outputs are multiplied by 2, since

there are only five plots of mixed flax and chickpeas, but ten monoculture plots. (Martin-Guay et al, 2018.)

The LER and RLO are then both compared to 1. Should the result of either equation be 1, it means that the land use efficiency is the same in mixtures as it is in monocultures. Should the result be greater than 1, this is an indication that the land use efficiency is greater in mixtures than in monocultures. Finally, should the result be less than 1, it is an indication that the land use efficiency is greater in monoculture than it is in mixtures (Martin-Guay et al, 2018.)

Results

Yield

The flax crops dominated mixtures, resulting in excellent yield, and the chickpea crops yield was dramatically reduced in the mixtures. Though the flax yield was reduced in mixed plots, the land use efficiency was greater in these plots according to the RLO.

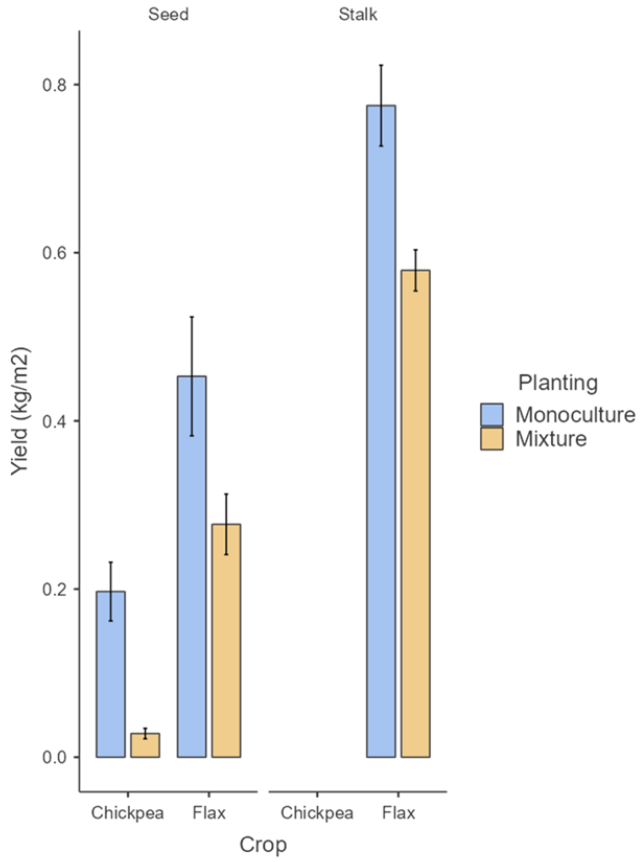

Figure 2: Yield of chickpea seed, and flax seed and stalk, in mixtures and monocultures. Error bars denote standard error of the mean (*n* = 5).

LER and RLO

According to the land equivalence ratio, there was no significant difference in land efficiency between mixed plots and sole plots (LER<1 in both mixed and sole plots.) However, the relative land output shows that, when we include flax stalk in the equation, there is a greater land efficiency (RLO>1.)

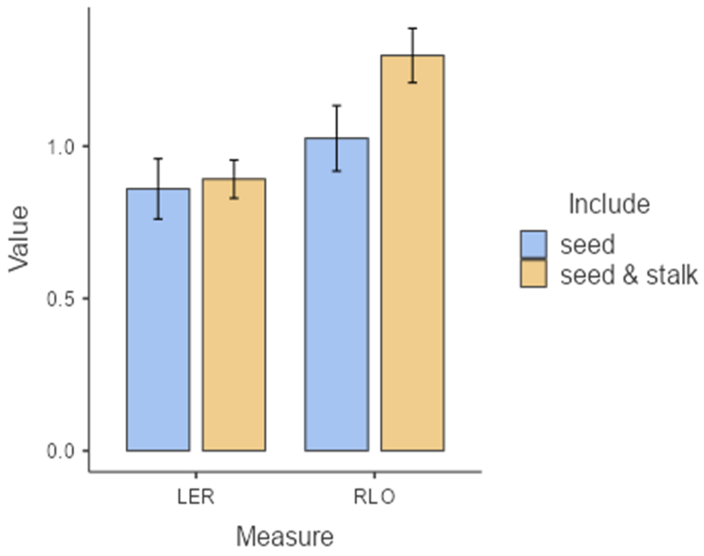

Figure 3: Land equivalence ratio (LER) and relative land output (RLO) for mixed plantings of flax and chickpea. Blue bars show values for seed only. Yellow bars show values when flax stalk is also included as an output. Error bars denote standard error of each mean (*n* = 5). RLO>1 when flax seed and stalk are included.

Discussion

Flax dominated the mixed plots, thus outcompeting the chickpeas in mixed plots. This may be related to the height of the flax compared to the chickpeas, or because of delayed growth of chickpeas due to poor initial germination. Flax mixtures had high yields in both seed and stalk, in comparison to their monocultures. Unfortunately, chickpeas had significantly decreased yields in the mixed plots compared to their respective monocultures.

The land equivalence ratio and the relative land output led to different conclusions in terms of their land use efficiency regarding intercropping. According to the RLO, intercropping led to greater land use efficiency. The RLO is preferred in this experiment due to its practicality in comparing land efficiencies on the same amount of land, as opposed to the LER which is more commonly used in terms of land sparing.

Mixing flax and chickpeas provided an improvement for the yield of flax, but reduced the yield of the chickpeas too vastly to be considered practical for an intercropping system. It is important to consider that mechanical harvest and separation of various crops is challenging in intercropped systems.

Despite a good climate for the production of flax in this region, there is no commercial market for British Columbia flax. BC lacks processing facilities, compared to France and China, which process 51% and 25% of the world's linen, respectively (Arslanoglu et al. 2022). Some small-scale BC farmers are still using ancient labour-intensive processing practices, but the mechanization of the flax to linen process could promote greater production of this sustainable crop and fabric.

Conclusion

Growing flax and chickpea in an intercropping mix results in a greater land use efficiency, when flax stalks are included, than growing them solely, according to the Relative Land Output. Chickpea yield was too vastly reduced in the mixed plots to make this a practical intercropping

system. The lack of flax processing industry in the Pacific Northwest is a significant challenge for farmers to consider.

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