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Evaluating the potential for multicropping in SE Kazakhstan : Double-cropping corn after winter triticale and winter oilseed rape

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Abstract

Double cropping is not presently a common practice in Kazakhstan. The long-term climate averages, however, suggest that the practice should be possible in the most southern portions of the country. The study described herein represents the first simultaneous evaluation of silage and grain corn crops sowing in SE Kazakhstan. Germplasm was chosen such that physiological maturity could theoretically be reached if seeded following winter triticale and winter oilseed rape. Results indicate that, considering the effect of climate change, it has been determined that even if the silage and grain yields are low, the corn grown as a second product has reached the harvest maturity and the product can be obtained. These results clearly demonstrate that with the appropriate selection of cultivar and watering possibility, there is a seeding date window where silage and grain corn can be expected to reach physiological maturity as a double crop in SE Kazakhstan.

Keywords: Double cropping, corn, Kazakhstan, winter triticale, winter oilseed rape.

Introduction

In agriculture, multiple cropping or multicropping is the practice of growing two or more crops in the same piece of land during one year, instead of just one crop. When multiple crops are grown simultaneously, this is also known as intercropping. Multiple cropping refers to growing two crops on the same field during the same year. One method of multiple cropping is double cropping, which is when one crop is grown after the first crop is harvested (Borchers et al., 2014). Compared with mono-cropping, double-cropping used climatic, land, labor, and equipment resources more efficiently and produced more total grain (Crabtree et al., 1990). This system involves the harvesting of one species followed immediately by the planting of another. Double-cropping increases the amount of time land is used for crop production and can increase potential profit (Pullins et al., 1997).

Double cropping system is interesting worldwide attentions both in developed and in developing countries (Lamessa et al., 2015). It will also advantageous for the increase of annual production (Yamane et al., 2016). Farmers would have improved demand for their products, double cropping would guarantee the land was not bare and exposed to erosive forces between crops (Moore and Karlen, 2013). However, the economic return per unit area and time are the main considerations for acceptances of a certain cropping system and yield is the primary agronomic parameter in any category of cropping system (Lamessa et al., 2015). Besides the direct benefit for crop production by increasing the number of harvest and the amount of biomass extracted, multiple cropping can improve the functioning of agricultural systems and reduce the environmental consequences sometimes associated with crop production (Gaba et al., 2015).

Agriculture plays an essential role in Kazakhstan's economic, social and environmental development. Once considered the breadbasket of the Soviet Union, Kazakhstan still suffers from the effects of agricultural and

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environmental mismanagement during the Soviet era. Over a third of Kazakhstanis' livelihoods depend directly or indirectly on the country's extensive rangelands for food, fodder, fuel and medicinal plants. Double-cropping system is not common product in Kazakhstan. Some farmers in Kazakhstan, in the Southeast Region, who used to plant milling wheat or barley as a first crop and corn as a second crop, want to double cropping to corn instead of mono-cropping. After Russian – Ukrainian war, due to crisis of cereals increased in the world, many farmers in SE Kazakhstan want to harvest the second-crop corn. Agro-climatic conditions of the SE Kazakhstan, where irrigated agriculture is developed, quite allows for an effective use of irrigated land throughout the year. However, in practice, farmers and peasant farms do not use these opportunities. Thus, after harvesting of early spring crops and winter wheat there is quite a lot of time (90-120 days) for cultivation of intermediate crops.

As in the whole world, Kazakhstan is one of the countries affected by climate change. Kazakhstan's hydro-meteorological service has observed a temperature increase in Kazakhstan over the last seventy years of weather observations. They observed not only a yearly average increase but also an increase in temperature during each season of the year. The average annual temperature increase is about 0.27°C every ten years. The highest increase has been observed for the autumn months (0.32°C/decade), the lowest in the summer months (0.2°C/decade) (Islyami et al., 2020). So far, there has been no scenario-based research on climate-change effects on agriculture in Kazakhstan.

To date, much of the information on the environmental, agronomic, and physiological constraints associated with double cropping has come from studies conducted in the US, South America, Turkey and China. We are unaware of any study that has explored the potential for double cropping for grain in SE Kazakhstan during the changing climate. The research described herein represents the first evaluation of the potential for double cropping in continental climate of SE Kazakhstan.

As the major limiting factor to double cropping in SE Kazakhstan is likely to be the interaction of seeding date and relative maturity for the summer seeded crop, this research aimed to evaluate the permissive window in late summer for seeding silage and grain corn crops. We hypothesized that, if the attainment of physiological maturity is primarily governed by seeding date, relative maturity, and their interaction, then with the appropriate selection of germplasm, silage and grain corn crops have the potential to be seeded as a double crop in SE Kazakhstan.

Material and Methods

Site and soil

The experiment was carried out on a light chestnut soil (65% sand, 2% silt and 33% clay fraction and soil textural class was named as Sandy clay loam. The pH was 7.2, soil organic matter content was 2,52%, $CaCO_3$ content was 5.80%, total N was 0.122%. Available nitrogen ($NH_4 + NO_3$) was 125 mg kg^{-1}, available phosphorus was 31 mg kg^{-1} and available potassium was 311 mg kg^{-1}), the field experiment was located on peasant farm " Bayserke Agro LLP farm " of Almaty Province of SE Kazakhstan 15 km from the city of Almaty, in the village of Ili Bayserke rafona Almaty region, Kazakhstan (Figure 1).

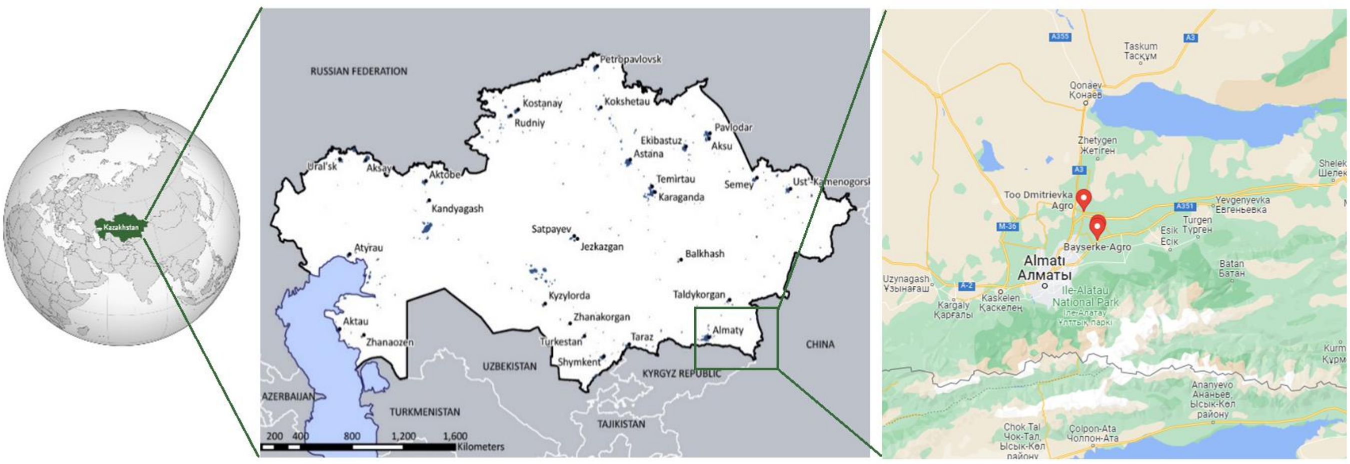

Figure 1. Study area

Climatic conditions

In study field, the summers are warm, dry, and mostly clear and the winters are freezing, snowy, and partly cloudy. Based on the Köppen climate classification system, the study area is classified as warm continental climate/humid continental climate (Köppen, 1931) with mild winters and long hot summers, with a daily average air temperature of 19-20°C and an annual precipitation of 215 mm at the experimental site.. The altitude of the study site is 850 m. The average temperature is –7°C in January and +28°C in July. Over the course of the year, the temperature typically varies from -11°C to 30°C and is rarely below -18°C or above 34°C. The hot season lasts for 3.8 months, from May 25 to September 18, with an average daily high temperature above 23°C. The hottest month of the year in Almaty is July, with an average high of 29°C and low of 16°C. The cold season lasts for 3.4 months, from November 24 to March 5, with an average daily high temperature below 4°C. The coldest month of the year in Almaty is January, with an average low of -10°C and high of -2°C (Figure 2).

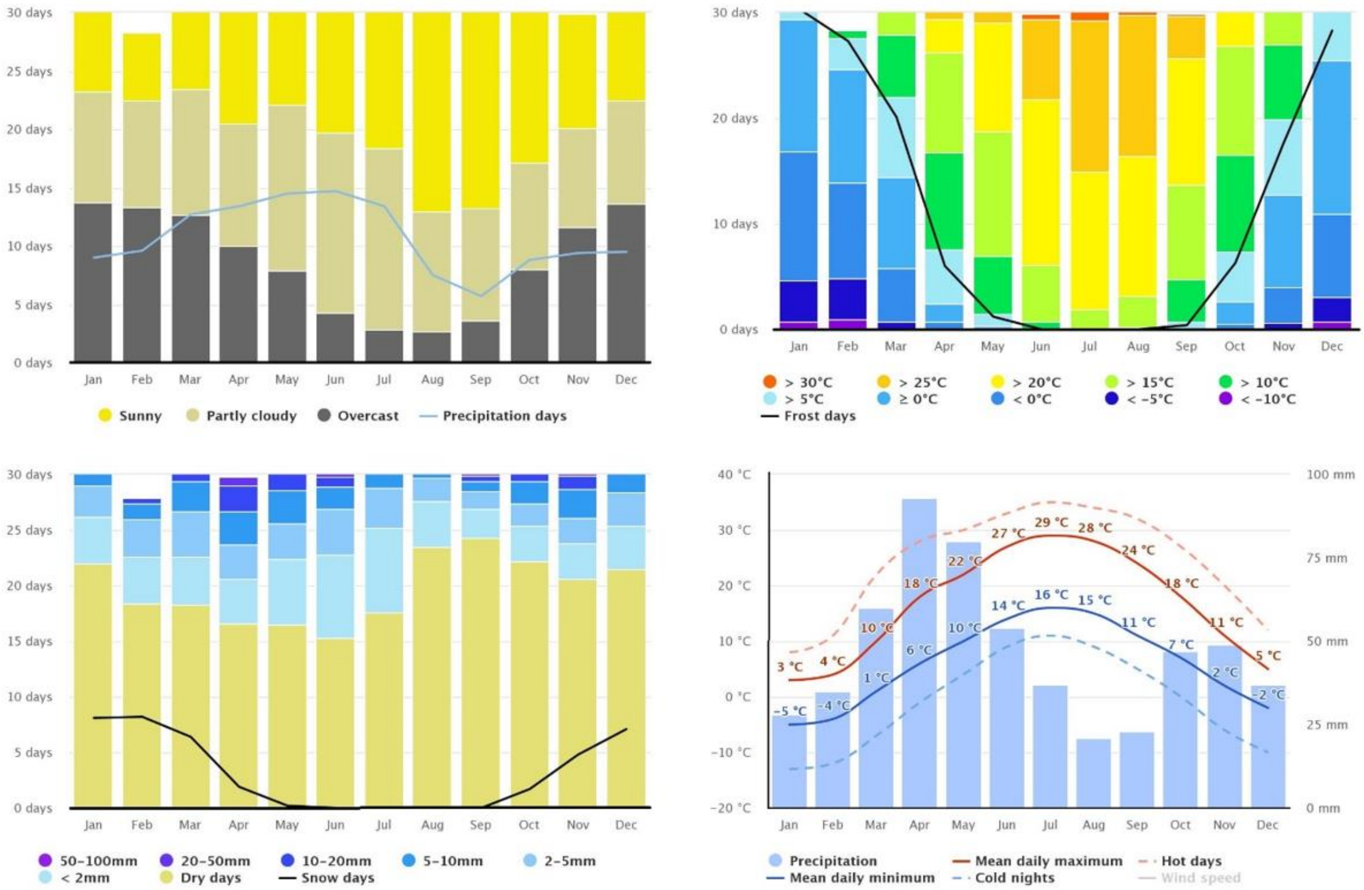

Figure 2. Climate conditions of the experimental area, Almaty, SE Kazakhstan

Experimental design

The experiment was carried out in "Bayserke Agro LLP" farm of Almaty Province of SE Kazakhstan. The trial started in September 2020 and consisted of 4 different double-cropping. These included winter barley (*Hordeum vulgare* L.), winter triticale (*Triticosecale*) and winter oilseed rape (*Brassica napus* L.), and ranged from monocultures to double corn crops for silage and grain (Table 1).

Table 1. Experimental design

No		The first crop	Second crop corn
1	WB	Monoculture winter barley	-
2	WT + SC	Winter triticale for grain	Silage corn
3	WT + GC	Winter triticale for green mass	Grain corn
4	SR + SC	Winter oilseed rape for grain	Silage corn
5	SR + GC	Winter oilseed rape for green mass	Grain corn

Practical constraints required the field trial design to be a split-plot design with one level of splitting. Fifteen experimental plots of 300 m^2 area (30m x 10m) separated by 1 m cement barriers were set in completely randomized block design with five treatments and three replications. The husbandry treatments were main plots; the crop rotations were sub-plots split within main plots. Sub-plot size was 15 m×9 m (plus 1m uncropped margin to avoid interactions due to soil movement). All crops (barley, triticale and seed rape) received 100 kg N ha^{-1} and 80 kg P ha^{-1} each year. The sources of fertilizers used were urea 46% N and double superphosphate 47% P_2O_5. Fertilizer applications are indicated in Table 2.

Table 2. Fertilizer applied to the different crops during the experiment

Crop	WB Winter barley	WT + SC Winter triticale	WT + GC Winter triticale	SR + SC Winter oilseed rape	SR + GC Winter oilseed rape
Fertilizer type	Double superphosphate (47% P2O5) Urea (46% N)	Double superphosphate (47% P2O5) Urea (46% N)	Double superphosphate (47% P2O5) Urea (46% N)	Double superphosphate (47% P2O5) Urea (46% N)	Double superphosphate (47% P2O5) Urea (46% N)
Fertilization rate	80 kg P_2O_5 ha^{-1} 100 kg N ha^{-1}	80 kg P_2O_5 ha^{-1} 100 kg N ha^{-1}	80 kg P_2O_5 ha^{-1} 100 kg N ha^{-1}	80 kg P_2O_5 ha^{-1} 100 kg N ha^{-1}	80 kg P_2O_5 ha^{-1} 100 kg N ha^{-1}
Fertilization date	10.Sep 2020 for DSP 10 Apr 2021 for Urea	10.Sep 2020 for DSP 10 Apr 2021 for Urea	10.Sep 2020 for DSP 10 Apr 2021 for Urea	10.Sep 2020 for DSP 10 Apr 2021 for Urea	10.Sep 2020 for DSP 10 Apr 2021 for Urea
Crop		**Silage corn**	**Grain corn**	**Silage corn**	**Grain corn**
Fertilizer type	-	Superphosphate (42% P2O5)	Superphosphate (42% P2O5)	Superphosphate (42% P2O5)	Superphosphate (42% P2O5)
Fertilization rate	-	40 kg P_2O_5 ha^{-1}	40 kg P_2O_5 ha^{-1}	40 kg P_2O_5 ha^{-1}	40 kg P_2O_5 ha^{-1}
Fertilization date	-	30 July 2021	20 June 2021	30 July 2021	20 June 2021

The sowing was done after the main crop monoculture winter barley was harvested in 25 May 2021, winter triticale was harvested in 25 May 2021 and winter seed rape was harvested in 26 May 2021. Grain corn was planted on 27 May 2021 and silage corn was planted on 08 July 2021 using a precision plot planter with variable seeding rate and row spacing capability. While 70 cm between rows were used in pure corn plantings, corn grain was planted 8 cm soil depth. Sowing and harvest dates, sowing rates and cultivar names per crop in each crop sequence are provided in Table 3.

Table 3. Sowing and harvest dates, sowing rate and cultivar name for each crop included in each sequence for the trial

Crop	WB Winter barley	WT + SC Winter triticale	WT + GC Winter triticale	SR + SC Winter oilseed rape	SR + GC Winter oilseed rape
Sowing date	25 Sep 2020	25 Sep 2020	25 Sep 2020	25 Sep 2020	25 Sep 2020
Sowing rate	120 kg ha^{-1}	120 kg ha^{-1}	120 kg ha^{-1}	20 kg ha^{-1}	20 kg ha^{-1}
Cultivar name	Zhuldyz	Taza	Taza	Kuban	Kuban
Harvest date	25 May 2021	25 May 2021	25 May 2021	26 May 2021	26 May 2021
Crop		**Silage corn**	**Grain corn**	**Silage corn**	**Grain corn**
Sowing date	-	08 July 2021	27 May 2021	08 July 2021	27 May 2021
Sowing rate	-	35 kg ha^{-1}	35 kg ha^{-1}	35 kg ha^{-1}	35 kg ha^{-1}
Cultivar name	-	Kazakhstan 43TB	Kazakhstan 43TB	Kazakhstan 43TB	Kazakhstan 43TB
Harvest date	-	10 Oct 2021	25 Sep 2021	10 Oct 2021	25 Sep 2021

With the planting 40 kg/ha pure phosphorus (superphosphate 42% P_2O_5) was used. In single corn and mixed planting, when the corn became 30 - 40 cm, ammonium sulfate fertilizer was added at a rate of 50 kg/ha pure nitrogen. After the last fertilization, weeds removal and covering roots with soil were carried out. Crop management not involving the treatments (e.g. seed date, application of herbicides or insecticides) was the same in all plots of a single crop and according to standard farm practice. Straw remained on the plots. At maturity, an area of 15×9 m was combine harvested and yield was standardized to t ha^{-1} based on the moisture content of a grain or seed subsamples and biomass of plants. The harvest stage of forages was done according to the dough period of corn. In the field experiment of the study; plant height, green herbage yield, hay yield, and protein ratios were determined.

Results and Discussion

The yield and yield component results of the plants grown as the first crop in the experiment are given in the Table 3. According to the results obtained, the yields of winter barley, winter triticale and winter oilseed rape were determined to be 5.76 t ha^{-1}, 6.38 t ha^{-1} and 2.52 t ha^{-1}, respectively (Table 3). In European countries, the product yield of winter barley is around 3.75 t ha^{-1}. In European countries, the highest winter barley yield is in Belgium with 7.82 t ha^{-1}, and the lowest winter barley yield is in Estonia with 1.30 t ha^{-1} (Garstang et al., 2010). There are many factors affecting the production of winter barley, such as climatic factors, barley variety and cultural practices (tillage, weed control, fertilization etc). On the other hand, it can be said that the yield results obtained for the winter barley from this study are above the European average. The yield of winter triticale in this study was 6.38 t ha-1, which is much higher than the yield results (1.59-2.43 t ha-1, Sukhanberdina et al., 2022) obtained from studies of different triticale varieties grown in Kazakhstan conditions. In this study, the yield of winter oilseed rape was determined to be 2.52 t ha-1. Similarly, the yield of winter oilseed rape was determined as 1.62-2.64 t ha-1 in Türkiye by Başalma (2004).

Table 3. At harvest yields of first crops

Plants	Plant Height (cm)	Biomass yield (t ha-1)	Grain or seed yield (t ha-1)	Yield of green mass, t/ha	Dry matter of yield (t/ha)	Crude Protein Content (%)
Winter barley	97	57.0	5.76	-	28.9	15
Winter triticale	110	64.8	6.38	64.8	31.4	13
Winter oilseed rape	118	67.6	2.52	67.6	32.1	30

The yield and yield component results of the silage corn as the second crop in the experiment are given in the Table 4. It was determined that the yield and plant height of silage corn grown as the second crop after oilseed rape (SR+SC) was higher than the silage maize grown after triticale (WT+SC). On the other hand, no difference was determined between the crude protein contents of the trials. In this study, it was determined that the height of the silage corn in the WT+SC and SR+SC trials varied between 70-80 cm, the yield of herbage varied between 9.4-10.5 t ha-1, the dry yield between 4.6-4.8 t ha-1, and crude protein content 6%. When compared with other studies, it was determined that the yield of silage corn obtained in this study was very low compared to the yield results obtained from other studies (Güneş and Acar, 2016; Güneş and Öner, 2019). Öztürk and Orak (2020) determined that the average plant height of different silage corn varieties (Calcio, Colonia, DK-743, Mas 74G, Pasha) plant height was 237 cm, herbage yield is 74.65 t ha-1 and dry yield was 6.83 t ha-1 in Türkiye. There are many factors affecting yield and quality in silage corn production. Geographical and climatic conditions (temperature, photoperiod and exposure time), cultural processes (planting time, harvest period, plant density and irrigation conditions), genetic characteristics of the variety are the factors that determine yield and quality (Cox et al., 1994). In this study, it was determined that some ecological factors limit the product yield, despite the growing of silage corn in Almaty ecological conditions.

Table 4. At harvest, silage corn yield and yield quality

Trials	Plant Height (cm)	Herbage yield (t ha-1)	Dry yield (t ha-1)	Crude Protein Content (%)
WT + SC	70	9,4	4,6	6
SR + SC	80	10,5	4,8	6

The yield and yield component results of the grain corn as the second crop in the experiment are given in the Table 5. It was determined that the yield and plant height of grain corn grown as the second crop after oilseedrape (SR+SC) was higher than the silage maize grown after triticale (WT+SC). On the other hand, no difference was determined between the crude protein contents of the trials. In this study, it was determined that the height of the grain corn in the WT+GC and SR+GC trials varied between 230-235 cm, the yield of biomass varied between 70.2-71 t ha-1, grain yield 7.3-7.4 t ha-1, the dry yield between 36-36.5 t ha-1, and crude protein content 10%. When compared with other studies, it was determined that the yield of grain corn obtained in this study was very low compared to the yield results obtained from other studies (Bozkalfa et al., 2004; Idikut et al., 2012). Just like in silage corn grown as a second crop, the low yield of corn grown as a second crop may be due to the non-optimal geographical conditions. On the other hand, even if the geographical and climatic conditions are not optimal, corn for grain can be grown as a second crop in Almaty, SE Kazakhstan climatic conditions. Kazakhstan has a continental climate and therefore cold winters and hot summers are observed. Agricultural areas in SE Kazakhstan experience a shortage of precipitation and climate change scenario shows the negative consequences of global warming in SE Kazakhstan. And also, climate change in SE Kazakhstan affects both the amount of water, water quality, corn yield and affect new technology adaptation. Even if the yield is low in changing climatic conditions, maize can be grown and yield can be obtained in SE Kazakhstan, even if it is low. However, production planning carried out in suitable climatic conditions with most productive varieties should be made by analyzing corn varieties and application areas. Water use efficiency in corn production could be increased by better water management using new irrigation and agronomic techniques.

Table 5. At harvest, grain corn yield and yield quality

Trials	Plant Height (cm)	Biomass yield (t ha-1)	Grain or seed yield (t ha-1)	Dry matter of yield (t ha-1)	Crude Protein Content (%)
WT + GC	230	70,2	7,3	36,0	10
SR + GC	235	71,0	7,4	36,5	10

In summary, the results of this research demonstrate that double cropping following winter triticale and winter oilseed rape are already possible in SE Kazakhstan. While season length still represents the most significant limitation to double cropping in SE Kazakhstan, our results clearly demonstrate that with the appropriate selection of variety or cultivar, there is a seeding date window where silage or grain corn can be expected to reach physiological maturity as a double crop.

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