

The present work was submitted to the Faculty of Engineering

**Correlations between sown dates and growth
parameters of some
common types of cultivars in Eastern Mongolia**

Bachelor Thesis

by

Tuguldur Bayargerel

Supervisor 1 / Examiner 1

Altanbadralt Sharkhuu

Supervisor 2 / Examiner 2

Enkhjargal Sodnomdarjaa

Ulaanbaatar/Nalaikh, 5/18/2023

Statutory Declaration

Bayargerel, Tuguldur

15622204748161

Last Name, First Name

Student ID Number

I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

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Tuguldur

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Abstract

In agricultural practice, finding a suitable time to plant the seeds is crucial as it can affect any cultivars' yield, germination, and growth. Since Mongolia has a continental climate with extreme temperature differences, it is important to study when the seeds should be planted.

This study aims to find the correlations between sown dates and growth parameters of 6 cultivars (barley, wheat, mustard, pea, oat, buckwheat). This study includes the analysis of the 6 cultivar growth parameters including root length, shoot length, and tiller number. The data is collected from eastern Mongolia, the Khentii province, and the statistical analysis was used on the data.

The result showed that earlier sown dates result in successful germinated seeds with the exception of buckwheat. For the physical growth factors, such as shoot length and root length, later sown dates result in higher shoot and root length because it correlates positively.

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1. Introduction

1.1 Background information

1.1.1 Crop Production in Mongolia

Historically, the main agricultural focus of Mongolia was on herding, a practice of bringing and caring for a group of animals. Most notably, the animals that Mongolians herded for centuries are called the five “jewels” which include sheep, goats, cows, horses, and camels as practicing plant agriculture was difficult due to the climate condition and location of Mongolia. The climate in Mongolia is very undesirable for cultivating and growing crops because the long and cold winters with short but very hot summers result in short growing seasons. This extreme fluctuation of temperatures alongside high altitudes and low precipitation caused Mongolians to adapt and practice nomadic pastoralism. Mongolians also avoided plowing the land since it was seen as disrupting the earth which conflicts with their tradition (1). Additionally, due to the riches and spoils from numerous wars and conflicts, Mongols could trade and buy certain crop products as opposed to cultivating them themselves (2), leaving plant agriculture underdeveloped throughout history. While there were some examples of crop production in Mongolia, it was mostly Chinese farmers who converted pastureland to cropland. In 1921, due to regime change, Mongolia became a socialist state under the Soviet Union. This socialist era launched the development of crop production in Mongolia. With the help of the Soviet Union, former herders began to work in state-owned farms and cultivate produce such as potatoes, wheat, and grains. By importing irrigation systems, mechanizations as well as know-how from the Soviet Union and implementing a new policy for agriculture, Mongolia tried to increase its efficiency and productivity of arable farming. While there were smaller problems such as inefficient techniques, environmental conditions, and an inexperienced workforce, it is safe to say that the Soviet Union built a foundation for the modern agriculture of Mongolia. The regime changed again when the Soviet Union fell and Mongolia transitioned from a communist state to a democratic country in 1990. As seen in Figure 1, due to the revolution in 1990, the total area for arable farming has decreased heavily. This fallout can be explained by market change and urbanization. During the Soviet Union regime, all land was owned by the government therefore farming was done in the most possible land area but due to the privatization of land, most farmers don't have the ability or the resource to continue farming in the same area. With the new government system and industrial economy,

many former herders and workers of farming migrated to the big cities and urban areas, searching for more opportunities and work.

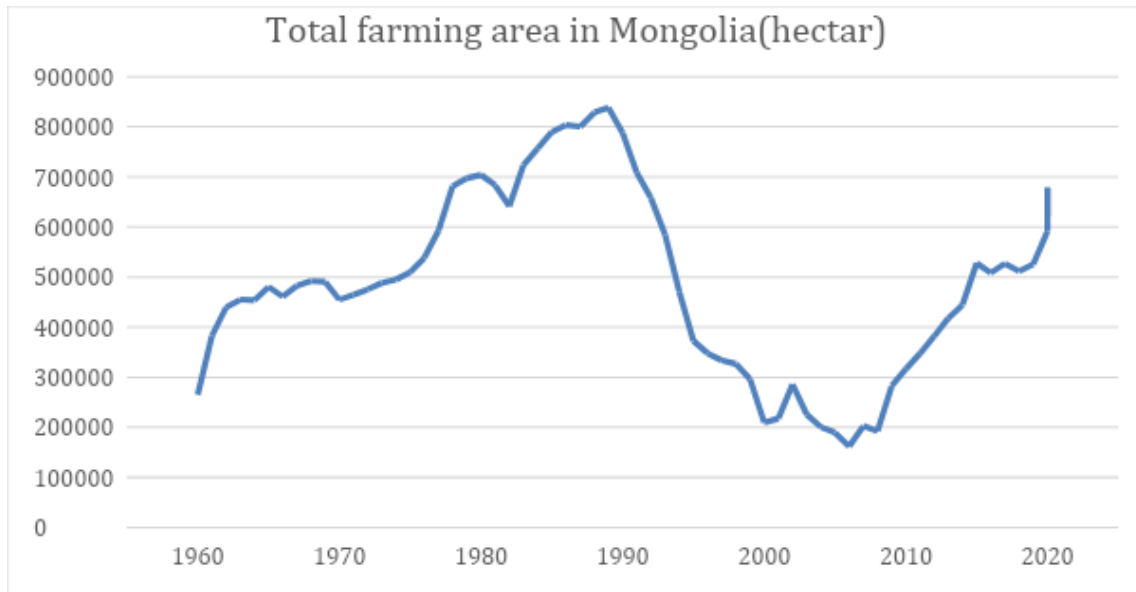


Figure 1 Total farming area in Mongolia from 1960 to 2022 (3)

Even though the total farming area has been decreasing since 1990, it starts to increase in 2008. During this time, several factors contributed to the rise and development of farming areas in Mongolia such as government policy, market demand, and climate change.

The biggest factor was the government policies that worked for the agriculture industry. The Government of Mongolia decided to make 2008 the “Year of the food supply and Security” (4). Starting this year, there were numerous activities done by the government such as land reforms, investments in countryside areas, and tax breaks for agricultural products. This decision was made due to the market demand. From 2005 to 2008, there was a clear increase in both the harvested crops from one hectare, indicating efficiency, and total export to China and Russia, indicating potential international markets.

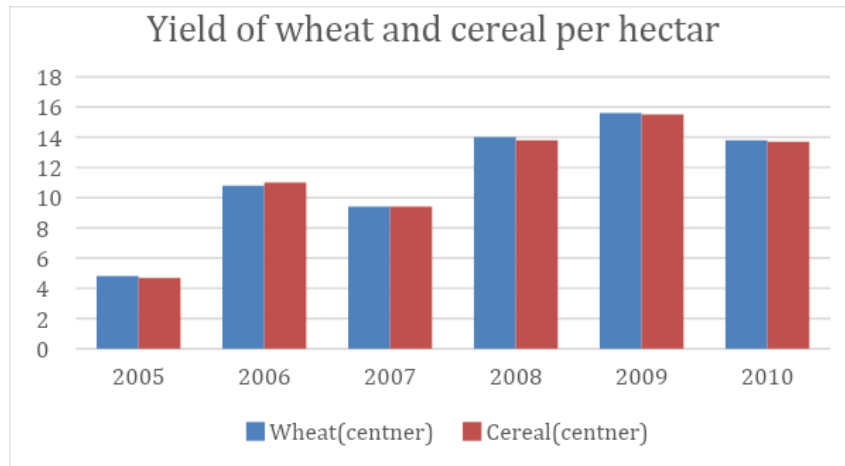


Figure 2 Yield of wheat and cereal per hectar (3)



Figure 3 Total exports by China (3)

1.1.2 Challenges

The most obvious yet unchangeable challenge to the agricultural practices of Mongolia is the climate and location. Located in East Asia between Russia and China, Mongolia is a landlocked country with no access to the ocean. This creates several conditions; limited water resources, highly fluctuant climate, and extreme temperatures.

Limited water resource leads to a lack of solid irrigation systems. While many countries have a solid irrigation system with no direct route to any major water supplies, Mongolia is not one of them. In terms of irrigation system technology, Mongolia has relatively weaker technology than some highly developed countries and combined with the limited water resource, a well-developed irrigation system is a difficult thing to achieve in

Mongolia. With no irrigation, crops are vulnerable to water stress, nutrient uptake, and reduced yield.

The total arable land in Mongolia was 1340480 hectares in 2020, about 0.86% of the total land

area (5). While Mongolia ranks 17th in total land area size, the fact that arable land is less than 1% shows the limitations of farming in Mongolia. As reported in 2021, agriculture along with forestry and fishing added 13.16% of the total GDP of Mongolia, making it one of the important industries in the country. (6)

Another challenge of agricultural practice is outdated technology and a lack of workforce. Since the beginning of its free market economy, many young adults tend to work and live in cities and populated areas. Also, the capital city is getting denser while rural areas stay scattered due to economic opportunities. This creates less workforce for the nomadic herders, as well as farmers since most agricultural practices, take place in rural areas. Even though agriculture is one of the major industries in Mongolia, there seems to be a lack of funding and support to achieve the next level of technological advances and research. From the business perspective, lack of workforce plus environmental conditions makes agriculture not fundable as people are not incentivized to spend money on a field with no huge returns

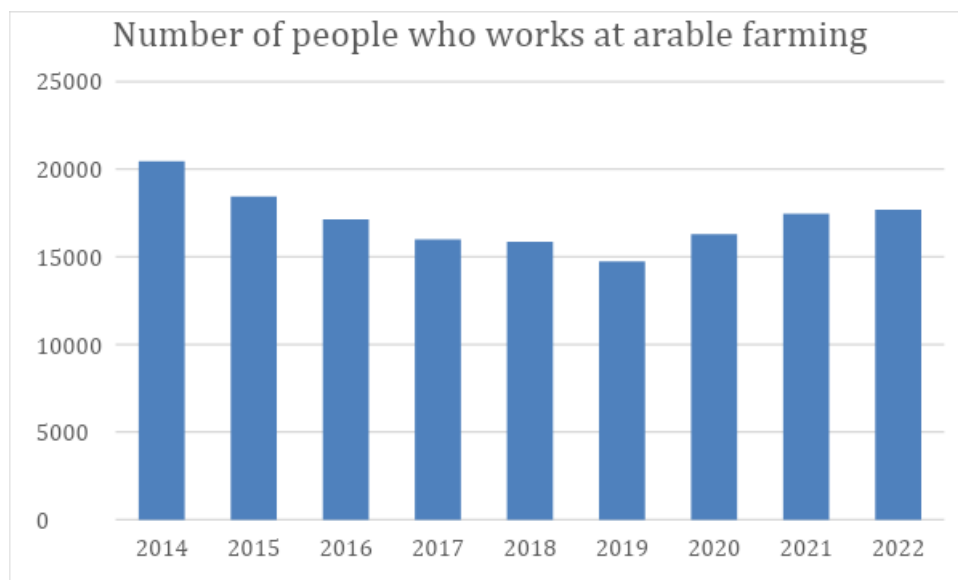


Figure 4 Number of people working in arable farming from 2014 to 2022 (3)

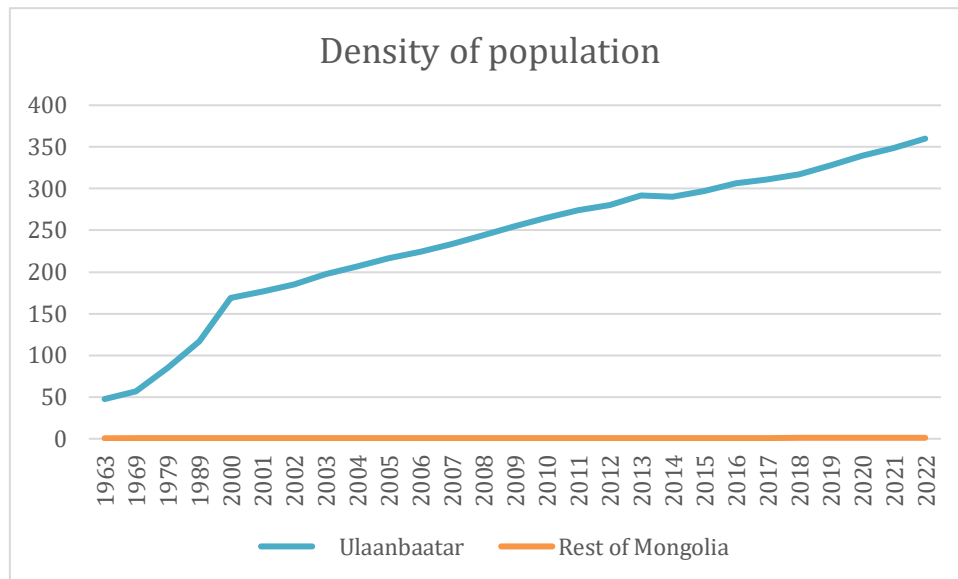


Figure 5 Density of population from 1963 to 2022 (3)

1.2 Sown date importance

1.2.1 Weather conditions

Sown date is one of the important factors influencing yield and growth in agriculture. Depending on the climate, temperature, and other factors, different sown dates result in different products. In Mongolia, the usual sown dates start around May because of the climate. Since the winter in Mongolia is long and cold, even after February which is the last month of the winter season, the cold remains in the soil as well as the atmosphere. This causes snowing in April which freezes the soil, reduces the infiltration of water to the soil, and more. In May, temperature rises and rain comes in, making the perfect condition for crops to be planted. Another crucial factor to note is the time of harvesting. Harvesting at the optimum time can both increase the yield and quality of the crops.

1.2.2 Moisture of soil

Another crucial part of the sown date is the soil moisture content. Moisture content is a crucial part of the germination process as most seeds need a certain amount of moisture for it to start the germination process. Spring is a very dry season due to less rain compared to the summer. Without enough moisture in the soil, the seeds are unable to grow their roots and stay in preserved mode until further moisture. By sowing early, we can use the already saturated moisture in the soil from the winter. If we sow too late, the moisture content will evaporate, leaving none for the cultivars.

1.2.3 Cold resistance of the seeds

Since the Soviet Union, farmers in Mongolia's agricultural knowledge of seeds and farming has been reliant on the old knowledge of the Soviet Union. Therefore, it has

become some kind of a tradition to plan on certain days, such as planting wheat on the first week of May. This approach is not scientific and there are not enough research and studies done on the cold resistance of the seeds. While this approach has worked for us for a few decades, we are not sure whether this knowledge is outdated or not. To test that, growing degree days should be used. Growing degree days are a measure of heat accumulation that is necessary for the crop to reach its maturity. Every cultivar has different growing degree days. For example, barley (*Hordeum vulgare*) needs 1290-1540 growing degree days for full maturity while oats (*Avena sativa*) need 1500-1750 growing degree days for full maturity given the same baseline temperature (7). By planting early and exposing seeds to coldness, we can determine the cold resistance of the seeds. Cold resistance is the ability to endure cold without damaging its growth. With our cold climate, if we can determine the cold resistance of certain seeds and how their growing factors are affected by cold, we can use this knowledge to other farmers and increase their yield and quality of the crop.

1.3 Objective of the study

The primary purpose of this study is to investigate the correlations between sown dates and growth factors of the most commonly cultivated plants in Eastern Mongolia.

By examining the correlation, we can find out how it affects growth factors and parameters. This study could provide insights that can help farming practices in Eastern Mongolia as well as a better understanding of the relationship between crop growth and environmental factors.

1.3.1 Questions and Hypothesis

Question 1: Does the sown date correlate with the growth parameters of the common cultivars in Eastern Mongolia?

Hypothesis 1: Sown date does correlate with the growth parameters of the common cultivars in Eastern

Question 2: Does an earlier sown date result in higher successful seed germination due to the moisture stored in the soil from the winter?

Hypothesis 2: Earlier sown date results in higher successful seed germination.

2 Literature review

2.1 Introduction to selected crop seeds and their literature background

2.2.1 Wheat

Wheat (*Triticum aestivum*) is a cereal grain belonging to the grass family *Poaceae*.

Wheat is a main staple due to it being the main ingredient of wheat flour and for livestock feeding. Therefore, it is the primary agricultural crop in Mongolia. The wheat sowing process usually starts around April and harvests around September in Mongolia. The Main wheat production provinces include Selenge, Bulgan, and Tuv with Selenge being the main wheat producer in Mongolia. (8)

The development stage of the wheat consists of 10 stages according to the Zadoks growth staging systems.

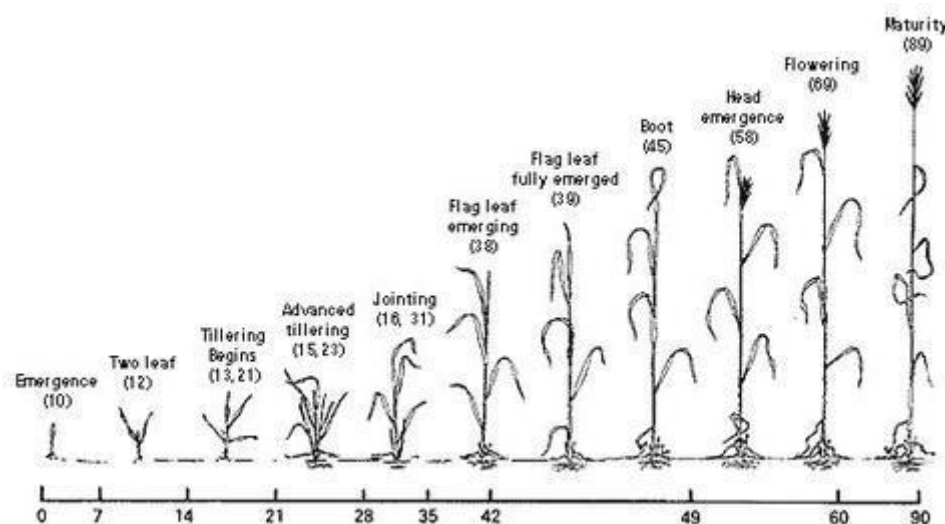


Figure 6 Wheat development stage (9)

Wheat is a C3 plant therefore it can be adapted to grow in colder environments. (8) Germination process can take about 3.5-10d depending on the soil moisture. While the germination process can tolerate between 4 to 40 Celsius degrees, the optimum temperature for the germination phase is 12-30 Celsius degrees. (9)

After germination, the next growth phase is floral initiation which it takes about 25-35 days with an optimum temperature of 4-10 degrees Celsius. Heading to Anthesis takes about 100 days to achieve a comfortable temperature of 12 degrees Celsius. And lastly, Physiological maturity is reached in about 140 days and while this can tolerate between 6 to 35.4 Celsius, the ideal condition for this phase is 21 degrees Celsius. (10)

2.2.2 Barley

Barley (*Hordeum vulgare*), a member of the grass family, is a cereal grain that is grown in temperate climates and used in multiple ways. Being one of the first cultivated grains, it is used for beer and distilled beverages as well as various foods and can be used as livestock feed. Barley is a highly nutritious grain full of dietary fibers, vitamins, and minerals. It has great health benefits due to its high fiber content and in Mongolia, is the 4th most-grown crop. It is self-pollinating, diploid species and able to thrive in poorer conditions compared to wheat. (11)

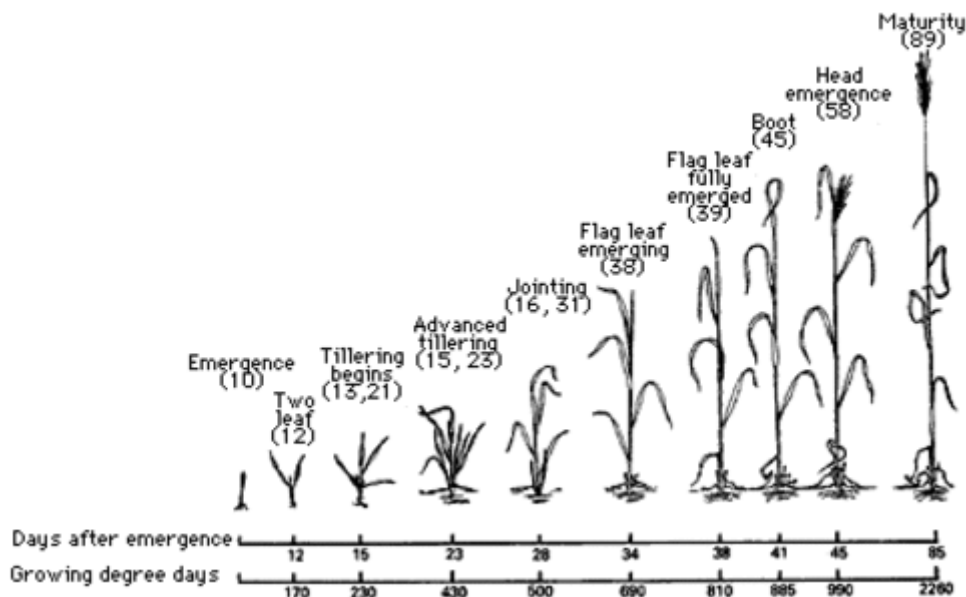


Figure 7 Barley development stage (10)

In the germination stage, the minimum temperature at that Barley can grow is 1 to 2 degrees Celsius. Around 35-45% of moisture content is necessary for barley to begin germination and around 35-degree days are required for visible germination. (12)

Soil moisture influences the both emergence and speed of germination of barley. More soil moisture results in a softer sowing area which can help the emergence. Hard soil with no moisture is difficult for the seed to push through, which halts the process of germination. (9)

2.3 Pea

Pea, known as *Pisum sativum*, is a highly nutritious type of legume that is part of the Fabaceae family. It comes in different varieties and can be used in many different ways such as boiled, steamed, sautéed, or added to soups and stews. Like barley, it is a great source of dietary fiber which benefits digestive health. With a life cycle of one year, Peas are planted annually.

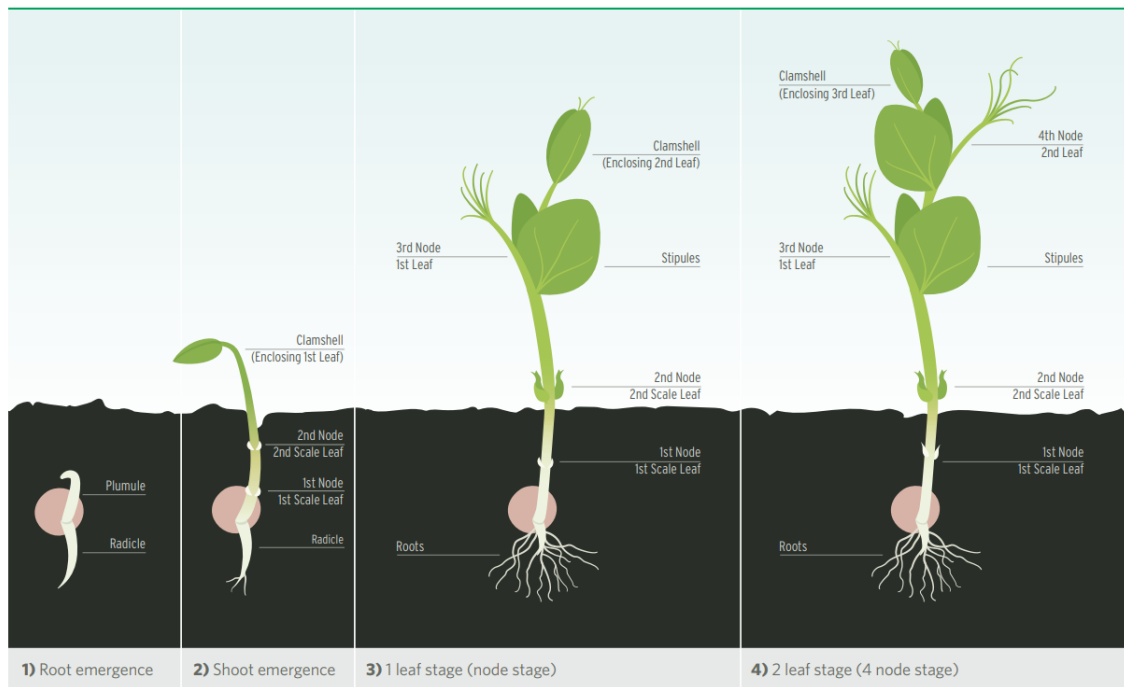


Figure 8 Pea development stage (12)

Peas can be planted in the temperature range of 5 to 22 degrees Celsius with the optimum temperature of 22 degrees Celsius. In the germination case, a higher temperature is more dangerous to the growth than frost while in the phase of development, frost causes more damage. In the flowering stage, lack of moisture will make damage to the pea crop. (14)

2.4 Buckwheat

Buckwheat, *Fagopyrum esculentum*, is a flowering plant in the knotweed family of *Polygonaceae*. It is a part of pseudo-cereal, a type of non-cereal grass that can be used as a cereal, and it is native to China and Tibet. It is a short-day plant, meaning it requires nighttime to germinate and flower. Buckwheat has triangular-shaped small seeds with hard shells and it has been studied for its health purposes due to its healthy nutrients including fiber and magnesium.



Figure 9 Buckwheat development stage

Buckwheat needs nighttime to flower, therefore it yields the best on cool nights. With the optimum temperature of 21 degrees Celsius, it grows the best in moist climates and while it can grow under a range of conditions, it suffers from extreme temperature differences. (15)

2.5 Mustard

Mustard, or *brassica juncea*, belongs to the Brassicaceae family. It is a short-day plant which means it needs both sunlight and darkness to grow and flower. It has a yellow flower that is self-fertile and can be pollinated by bees. It is known for its high tolerance towards heat and water stress therefore it is suitable to grow in Mongolia. With its high amount of protein, fiber, and essential minerals, mustard is a great crop that has both medicinal and food uses.

2.6 Oat

Oat, *Avena sativa*, is a cereal grain that belongs to the *Poaceae* family. They are an annual plant that requires more daylight to initiate development. Usually, they are wind pollinated and in order to make a viable seed, they require cross-pollination. Oats can be used as livestock feed and food such as cookies, cupcakes, and oatmeal.

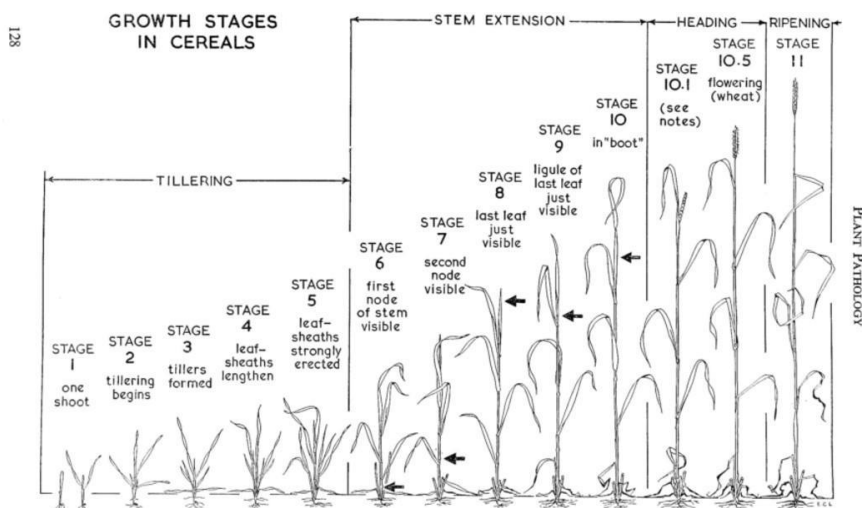


Figure 10 Oat development stage (9)

2.2 Effects of sowing date on crop parameters

2.2.1 Introduction

Sown date, or sowing date, is the date or timing when the crops are planted in the soil. This is an important factor in crop agriculture as it can directly affect the success of production. In Mongolia, the common sown date is around May 5th or May 15th and this is the former practice of the Soviet Union that is transpired and passed down to the future generation of farmers. Sown date affects crop yield, seed germination, crop growth, and profitability. The objective of this research is to find a correlation between sown date and growth parameters of given 6 cultivars, therefore it is necessary to state the terms

2.2.2 Key Terms, potential factors, and Expectations of Correlation

Key terms

Terms	Definition
Sown dates	The specific date used to cultivate the seeds for the production of crops
Root length	Measurement of the length of the root from the root tip to the root end
Shoot length	Measurement of the length of the above parts of the crop excluding roots
Growth parameters	Any physical measurable parameters that can be used to assess the growth of the cultivar such as root length, shoot length etc.
Yield	Amount of crop harvested from the given area. Can be used to assess the profitability and crop production
Tillering	A process where additional shoots energy from the stem of the crop. Can be used to assess yield and growth.

The expectation of correlation between sown dates and growth parameters comes from many different reasons. The sown date is a factor of the environment, meaning different sown dates result in various conditions of the environment. Environmental factors that are influenced by sown dates are precipitation and weather. Precipitation, such as rain and snow, can directly influence the growth and germination process of the seeds because seeds use water for the process of seed imbibition. It is basically like drinking water for the seeds, it hydrates seeds which in turn expands the seed metabolic activities, causing growth and root emergence therefore water is important in the seed germination process.

While precipitation is part of the weather, in terms of growth parameters, there are also multiple factors of the weather that can impact the growth of the seeds. Temperature is the most prominent factor of the weather that is easily measurable and changes

according to the sun's position and other factors. Therefore, with the constant temperature change around the day, different plants have adapted to require certain specific temperatures for their germination due to their genetics. For example, wheat is adapted to grow in colder environments therefore its optimum temperature for germination is around 4-10 degrees Celsius while buckwheat has a much higher optimum temperature, with around 21 degrees Celsius. With each cultivar having a different optimum temperature for growth, weather can affect the germination process as well as a growth process. Temperature is basically a measure of the average kinetic energy of atoms around the crops therefore more temperature equals more energy, and more energy results in easier energy transitions for the cultivar to grow.

Another important factor that affects growth is light, especially sunlight. Some seeds need sunlight for germination and growth and there are seeds that require nighttime to grow. In most plants, photosynthesis is a process where sunlight energy is used to initiate a reaction that produces chemical energy for the plant to use and grow. Also, some plant species, such as lettuce and pepper actually require light to initiate their germination process. In our experiment, buckwheat is a short-day plant, meaning it requires nighttime to grow this is an energy conservation method as it is protecting its flower, therefore growing stronger.

There are other factors such as soil condition and humidity. Since soil is the growing medium for seeds, it needs to have growing conditions. For plants to grow, it requires nutrients and water from the soil. Nutrients such as nitrogen, phosphorus, and potassium have a crucial role in plant growth. Nitrogen is essential for the growth of the plant and insufficiency with nitrogen leads to chlorosis, stunted growth. As for phosphorus, it plays a role in energy transfer and strong root systems. Lastly, without enough potassium, plants can have weak stems and lower yields. Humidity also plays a role in plant growth because when humidity is too low, the transpiration rate increases due to the water content difference between the outside and inside of the plant therefore plant loses its water fast, resulting in less metabolic reactions.

2.2.3 Correlation between growth parameters and sown dates

Several studies are done to investigate the correlation between growth parameters and sown date of various cultivars in different regions of the world. Additionally, there are also studies made to investigate the correlation between sown date and yield. This section presents a review of studies to provide knowledge on this topic.

Mitali et al., 2022 (18) conducted a study examining the impact of sowing dates on wheat varieties. An experiment was conducted in Nepal during the winter season and the

methodology used three replications with four different wheat varieties. Key measurements were spike length, tillers, grain yields, 1000 grains weight, plant height, and straw yield. For the result, the sown date had an effect on the spike length, tillers, grain yield, and 1000 grains weight while sown date did not affect plant height and straw yield. A difference to notice is that this study was done on winter wheat, with the sown dates in November and December,

Ortiz-Monasterio et al., 1994 (19) conducted an experiment examining the date of sowing and its effect on grain yield and yield component of spring wheat. Unlike our experiment, this study was done with irrigated field. This study was focused on temperature and photothermal quotient, which is the effect of pre-heading radiation and temperature. For the result, it can be seen that the optimum date for the spring wheat was mid-February in India. An important thing to note is that India has a different climate than Mongolia, therefore sowing in winter is difficult for most farmers due to extreme cold.

Prince et al., 2018 (20) conducted an experiment on the effect of sowing dates with 4 dates in November and December. This experiment was conducted under limited irrigation and parameters such as tiller number, dry matter, 1000 grain weight, grain yield, and straw yield were measured. It can be seen that earlier dates had a better effect on the measurement due to temperature differences. Since the temperature from November to December decreases, it can also make conclusion that decreasing temperature lowers the growth parameters.

The experiment done in Iran showed that earlier sowing dates resulted in higher seed yields. Basil was researched with dry farming conditions and early sowing dates showed higher plant height, umbrella per plant, and seed per umbrella. (19) In both cases, it was too late when planting therefore it caused a significant decrease in yield.

3 Methodology

3.1 Study area

3.1.1 Introduction

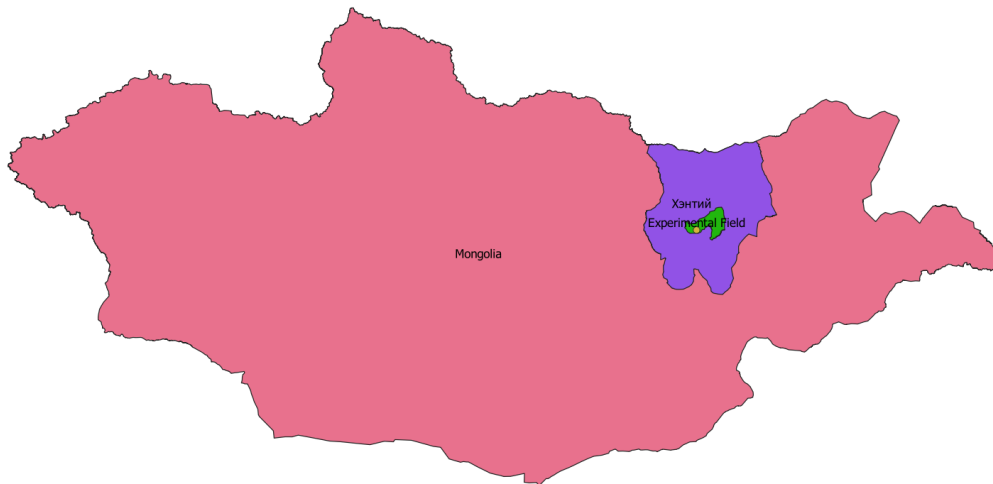


Figure 11 Study area on the map of Mongolia

The field experimental work was performed near the Ulziit area, in Kherlen soum, Khentii province. The total duration of the experiment was carried out from April to August and field study for sampling and experimental analysis for samples were done during the period from May 3rd to August 21st, 2022. The field study and experimental laboratory works were performed in “M-Agro” LLC under instructions by Lead agronomist Dr. Altanbadralt. This experiment was done in an agricultural company therefore there were plenty of resources and experts in this field.



Figure 12 Study area on the map of Khentii province



Figure 13 Study area on Google Earth

3.1.2 Climate

Climate in Mongolia can be described as combination of different temperatures because of its location and the country size. In the north, precipitation is the highest which is on average 20 to 35 centimeters per year while in the south, precipitation is the lowest with 10 to 20 centimeters. With the Gobi Desert in the south, and no direct route to any oceans, Mongolia is a dry country with average sunny days of 257. According to the Koppen classification system, Mongolia has 7 different types of climate conditions inside it.

Khentii province lies on the temperate continental climate (Dwb) which is in the north and eastern part of Mongolia. The temperate continental climate is described as a Monsoon-influenced warm-summer humid continental climate, with the coldest month averaging below 0 Celsius and all months averaging below 22 temperatures, and with 4 months averaging above 10 Celsius. This type of climate is characterized by the ten times as much rain in the wettest month of summer as in the driest month of winter.

The Khentii ranges are characterized by their vast temperature differences during the seasons. This difference causes damage to the soil as they can't accumulate sufficient amounts of nutrients in this area. With an aridness coefficient of less than 1 and radiant heat of less than 1500, this area is not known for its agricultural practices until recently.

Mongolia map of Köppen climate classification

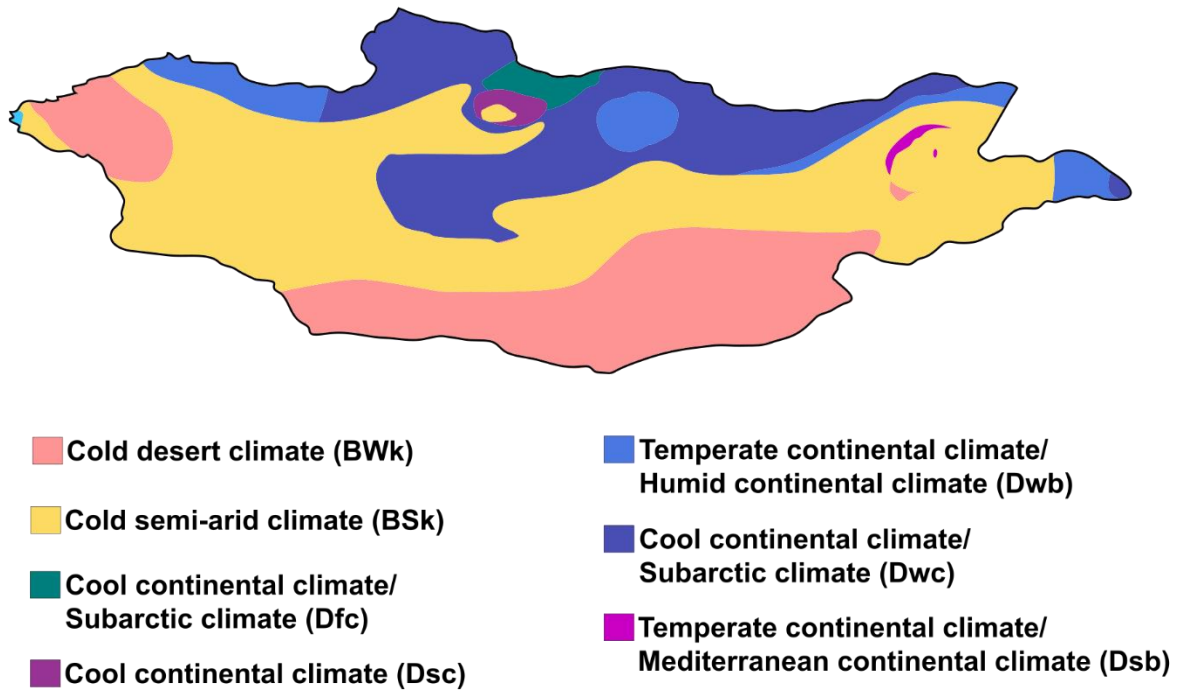


Figure 14 Mongolia map of Köppen climate classification (13)

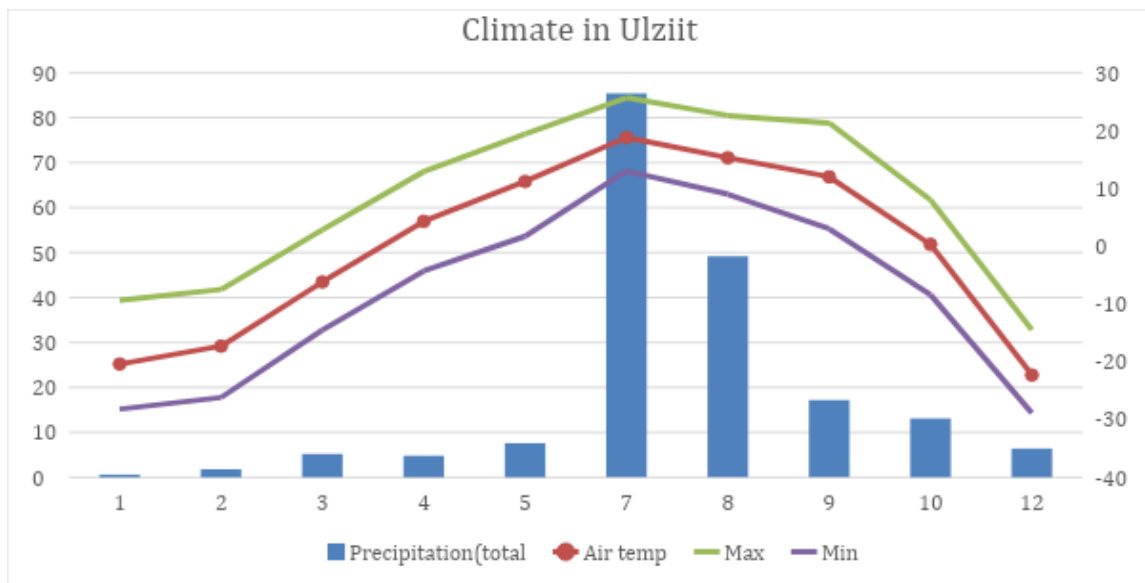


Figure 15 Climate in Ulziit in 2023

3.1.3 Soil type

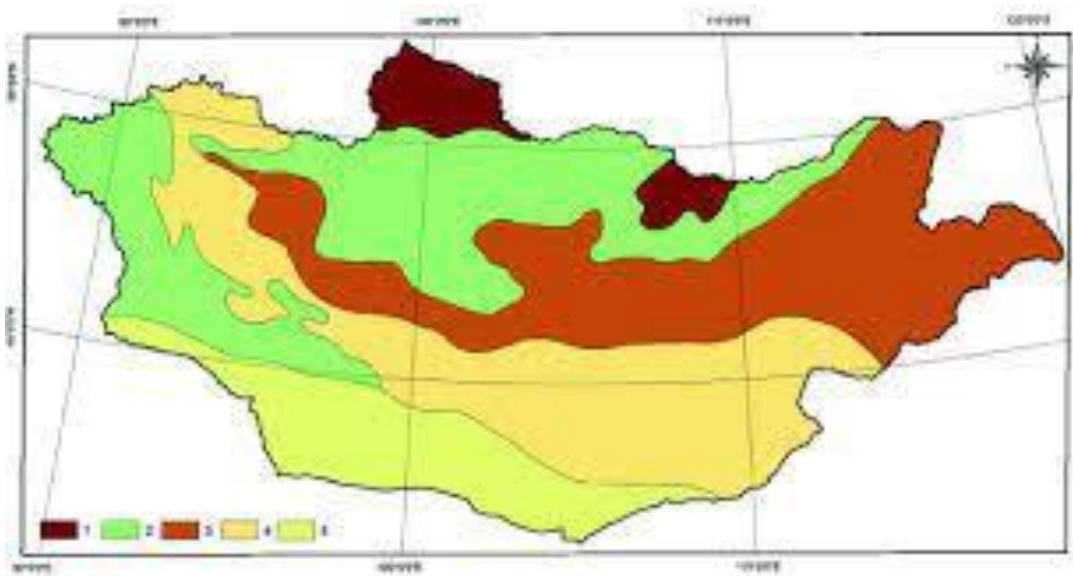


Figure 16 Soil belt and zones of Mongolia (14)

While Mongolia has 5 intercontinental soil areas, khentii province belongs to the group of mountain taiga belt with cryomorpho-taiga and derno taiga soils.

This type of soil is around khentii and khuvsgul provinces. Since it is closer to the permafrost region, the soil and its contents are affected by the permafrost. It affects by forming gravels in the soil layers, making it difficult for different soil layers to be identified. Soil thickness is lower than 80cm and the humus content fluctuates between 11 and 20%. (22)

This region is known as mountain meadow steppe podzolic.

3.1.4 Hydrology

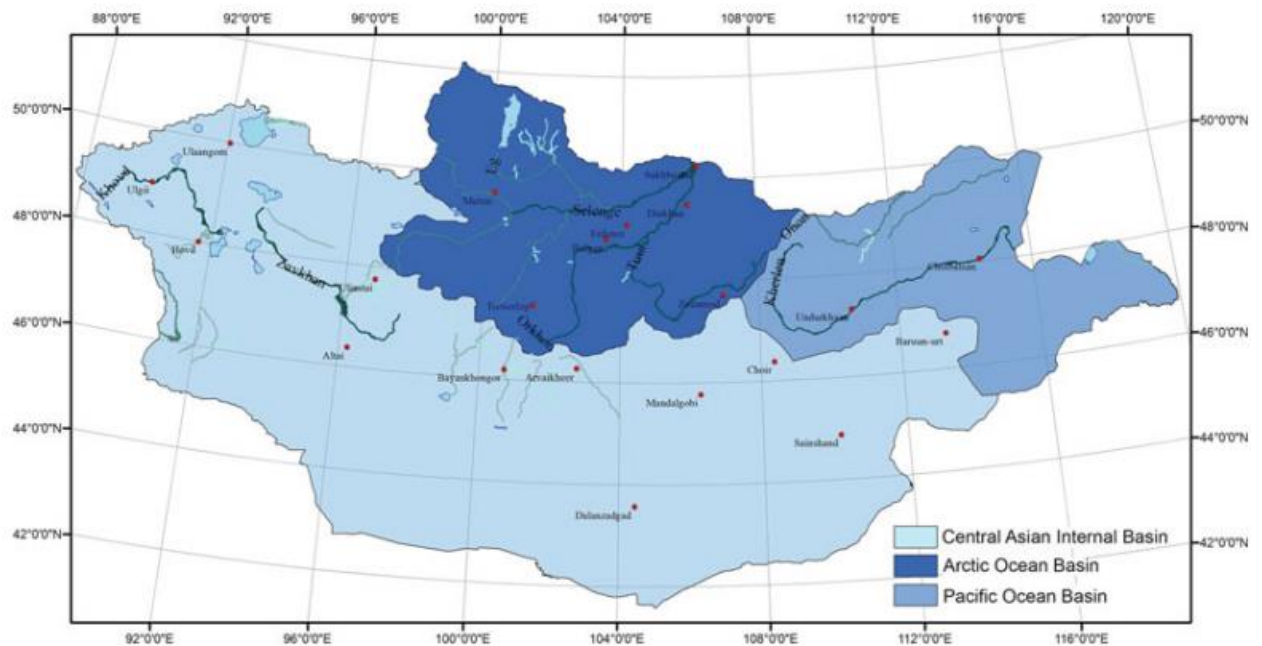


Figure 17 Hydrological drainage basins of Mongolia (15)

The area around the experimental field is around the Pacific Ocean basin, one of the 3 basins in the Mongolia. The river basin occupies 12 percent of the total area in Mongolia. There are two main rivers, Onon and Kherlen, which originated Soil the Khentii mountains and flow around the area. Kherlen River is the closest river to the experimental field. With the basin area of 7350 km² and runoff surface height of 2200 m, the kherlen-undrukhaan River is the closest to our experimental field area. (22)

3.2 Scheduled time table of the research work from April to July 2022 at M-Agro LLC

Table 1 Scheduled timetable of the research study

No	Tasks	April				May				June				July			
		Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
1	Introduction																
1.1	Introduction to the experiment																
1.2	Field visit																
1.3	Exploring methods																
1.4	Detailed research on the topic																
2	Field study																
2.1	Observation on the field																
2.2	Plantation of the seeds																
2.3	Sample Collection																
2.4	Field maintenance																
2.5	Work on other projects																
3	Laboratory work																
3.1	Measurements																
3.2	Data entry																
3.3	Data processing																

3.3 Field study

3.3.1 Cultivating

The cultivation process started in April 12th and ended in May 20th. A planter, farm implement that is attached to a small tractor, is used to sow seeds into the soil. Since the planting area is smaller than conventional planting, industrial seed planters can't be used. By filling the seed planter with given 6 cultivar seeds and specifying the seed rate using trial and error method, we were able to accurately plant the seed with intended seed rate. Since the soil depth at which seed can be sown must be within range that allow seed to reach the moisture of the soil, it was maintained at 5 cm.



Figure 18 Tractor attached with seeded in study area

3.3.2 Sampling

To avoid the selection bias and ensure the random selection, we used a custom made 1m x 1m wooden frame. The purpose of this frame is to ensure that our sampling area is around 1 meter squared so that the measurements from this frame can be calculated easily. The sown dates and sampling dates are shown in table 1.

Table 2 Sown date timetable

Sown date														
Apr.12	Apr.12	Apr.15	Apr.15	Apr.19	Apr.19	Apr.22	Apr.26	Apr.29	May.3	May.6	May.10	May.13	May.17	May.20
Wheat 6-May	Wheat 6-May	Buck.w 18-May	Buck.w 18-May	Wheat 11-May	Wheat 11-May	Buck.w 25-May	Wheat 19-May	Buck.w 1-Jun	Wheat 26-May	Buck.w 8-Jun	Wheat 2-Jun	Buck.w 15-Jun	Wheat 9-Jun	Buck.w 22-Jun
Barley 6-May	Barley 7-May	Oat 18-May	Oat 18-May	Barley 11-May	Barley 11-May	Oat 25-May	Barley 19-May	Oat 1-Jun	Barley 26-May	Oat 8-Jun	Barley 2-Jun	Oat 15-Jun	Barley 9-Jun	Oat 22-Jun
Mustard 6-May	Mustard 6-May	Pea 18-May	Pea 18-May	Mustard 11-May	Mustard 11-May	Pea 25-May	Mustard 19-May	Pea 1-Jun	Mustard 26-May	Pea 8-Jun	Mustard 2-Jun	Pea 15-Jun	Mustard 9-Jun	Pea 22-Jun
Wheat 5-May	Wheat 7-May	Buck.w 18-May	Buck.w 18-May	Wheat 11-May	Wheat 11-May	Buck.w 25-May	Wheat 19-May	Buck.w 1-Jun	Wheat 26-May	Buck.w 8-Jun	Wheat 2-Jun	Buck.w 15-Jun	Wheat 9-Jun	Buck.w 22-Jun
Barley 5-May	Barley 7-May	Oat 18-May	Oat 18-May	Barley 10-May	Barley 10-May	Oat 25-May	Barley 19-May	Oat 1-Jun	Barley 26-May	Oat 8-Jun	Barley 2-Jun	Oat 15-Jun	Barley 9-Jun	Oat 22-Jun
Mustard 5-May	Mustard 5-May	Pea 18-May	Pea 18-May	Mustard 10-May	Mustard 10-May	Pea 25-May	Mustard 19-May	Pea 1-Jun	Mustard 26-May	Pea 8-Jun	Mustard 2-Jun	Pea 15-Jun	Mustard 9-Jun	Pea 22-Jun
Wheat 4-May	Wheat 6-May	Buck.w 18-May	Buck.w 18-May	Wheat 10-May	Wheat 10-May	Buck.w 25-May	Wheat 19-May	Buck.w 1-Jun	Wheat 26-May	Buck.w 8-Jun	Wheat 2-Jun	Buck.w 15-Jun	Wheat 9-Jun	Buck.w 22-Jun
Barley 4-May	Barley 6-May	Oat 18-May	Oat 18-May	Barley 10-May	Barley 10-May	Oat 25-May	Barley 19-May	Oat 1-Jun	Barley 26-May	Oat 8-Jun	Barley 2-Jun	Oat 15-Jun	Barley 9-Jun	Oat 22-Jun
Mustard 4-May	Mustard 4-May	Pea 18-May	Pea 18-May	Mustard 10-May	Mustard 10-May	Pea 25-May	Mustard 19-May	Pea 1-Jun	Mustard 26-May	Pea 8-Jun	Mustard 2-Jun	Pea 15-Jun	Mustard 9-Jun	Pea 22-Jun

Due to a difficulty in manpower as well as in expertise, in first stage of the sampling process, we were not able to sample the same sown date areas within a day. For example, we spent 3 days to collect all the samples and data from the April 12th area, leaving a room for potential small mistake.



Figure 19 Custom-made wooden frame for sampling

The sampling process is

1. Place the frame randomly in the given field
2. Count how many seeds are germinated
3. Use shovel to dig into the soil to retrieve the samples in the soil
4. Hand pick the samples and collect them in a plastic bag

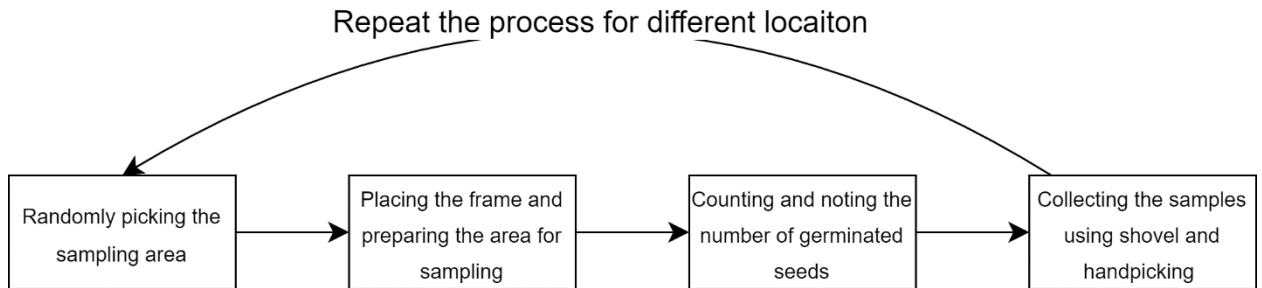


Figure 20 Flowsheet for the sampling process

By counting the seeds number, we can understand how many seeds are germinated and, on a path, to grow. By using the shovel, we can ensure that the roots and shoots are not snapped when collecting. By carefully handpicking the samples from the soil, we can also ensure that our collected samples are in best condition to measure.

Each cultivar had its own planting area of 15 x 40m. In total of 600 meters squares area, and the seed rate for it was 100kg/hectare.

Since the total area for 1 crop planting square is 600 meter squared, we placed the wooden frame 3 times in 1 planting square. In total we would get a total of 9 different samples from each sown date given that there are 3 replicas and we collected 3 samples from 3 replicas. As for the number of samples we collected, if the total amount of crops in the frame was above 50, we only collected the randomly picked 50 samples for the laboratory measured. When the number doesn't reach 50, we collected everything that was in the frame.

3.3 Laboratory work

By placing the samples and using refrigerator, we were able to store and measure the samples we collected from the field. We used a ruler to measure the length of the shoots and roots by placing them in a black table. Since the roots were in deep soil, we used a bucket of water to try to separate the soil from it. We then recorded the data from the measurement.

4 Results

In this section, there are numerous tables and graphs showing the growth parameters as well as yield and germination for the 6 cultivars. For pea and oat, there was no yield data obtained. Bar graphs and line graphs were used to describe the relation between a measurement and sown date and in statistical analysis, the correlation coefficient and p values were calculated. Since there are only 6 sown dates, we used a significance level of 0.1. If the p values are higher than significance level, we can assume that the correlation between given parameter and sown dates are statistically significant.

4.1 Mustard

4.1.1 Germination

From the number of germinated seeds per square, we can see that April 19th had the highest number of successful germination while after May 3rd, the number declined. Therefore, we can say that the earlier sown dates are better for the successful germinations. This data was collected after 22 days, which is way past the germination duration of typical mustard seed. From the statistical analysis, the correlation coefficient between the sown date and average number of germinated seeds per square meter was -0.54, which indicated a strong negative relationship. The P value from this coefficient was 0.27 which is considered as not significant with the significance level of 0.1 and the R squared value for this graph was 0.29, which also doesn't support any strong relationship.

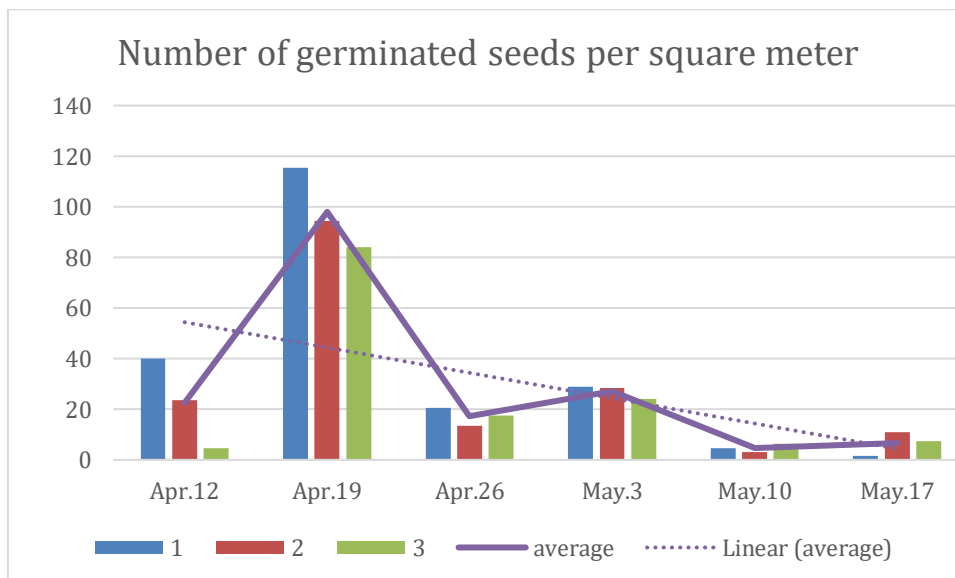


Figure 21 Number of germinated seeds per square meter

Table 3 Statistical analysis of number of germinated seeds

Mustard	Replica 1	Replica 2	Replica 3	Average
Apr.12	40.00	23.50	4.50	22.67
Apr.19	115.50	94.50	84.00	98.00

Apr.26	20.50	13.50	17.50	17.17
May.3	29.00	28.50	24.00	27.17
May.10	4.50	3.00	6.50	4.67
May.17	1.50	11.00	7.50	6.67
Correlation	-0.66	-0.52	-0.37	-0.54
Multiple R	0.66	0.52	0.37	0.54
R Square	0.43	0.27	0.14	0.29
t-score	1.75	1.21	0.80	1.28
p-value	0.15	0.29	0.47	0.27

Each correlation value and multiple R of replica data suggest that there is an inverse relationship between number of germinated seeds per square meter and sown date. Each replica shows low R squared value which indicates that low proportion of variability in number of germinated seeds per square that can be explained by sown date. By using the t-score, we calculated the p value and each p value is less than common significance level of 0.1 therefore we can conclude that the correlation between sown dates and number of germinated seeds per square is not significant statistically.

4.1.2 Growth factors

To determine the growth, we measured the root and shoot length of the mustard. From the root and shoot length of the mustard, the graph shows that May 10th has the highest value in both shoot and root length. Since the graph is uprising from April 12th to May 17th, this shows that later sowing dates are better for the growth of the root and shoot length. On the other hand, April 12th had the shortest shoot and root length.

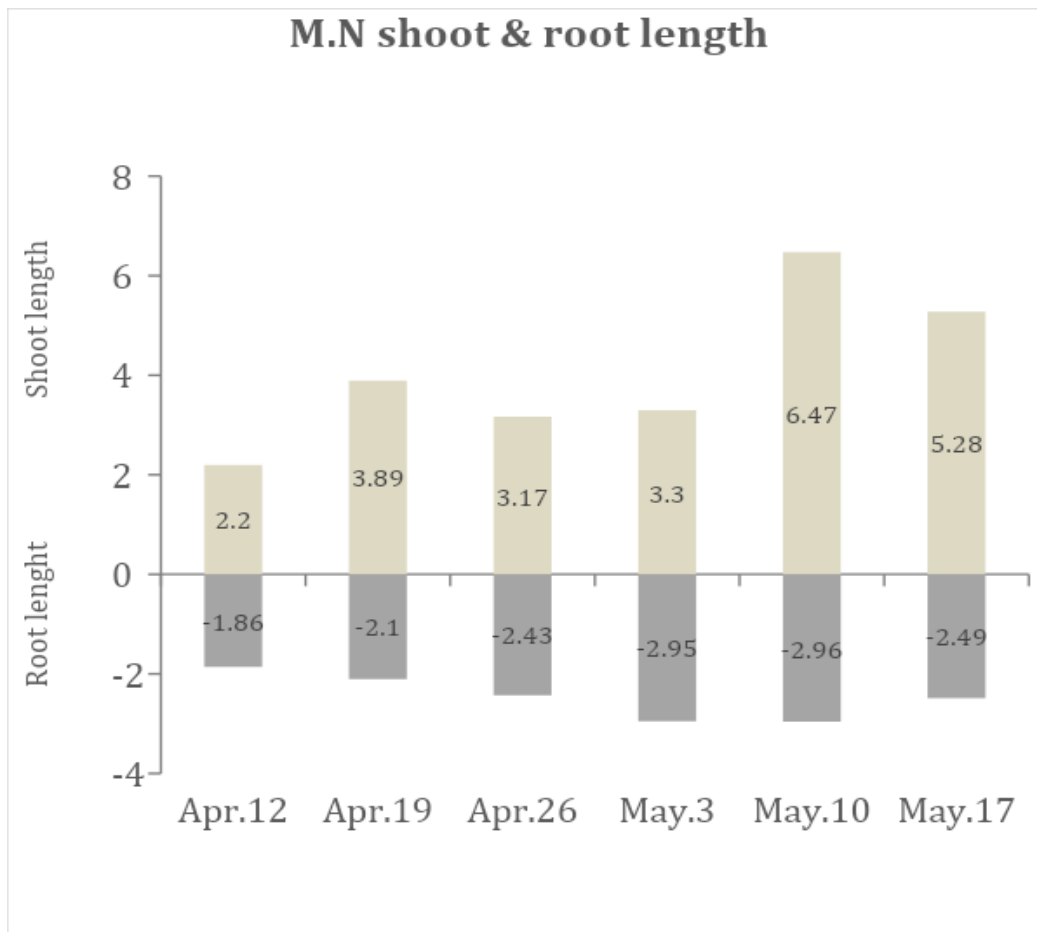


Figure 22 Shoot and root length averages of mustard

Table 4 Statistical analysis of root and shoot length

Mustard	Root length				Shoot length			
	Replica 1	Replica 2	Replica 3	Average	Replica 1	Replica 2	Replica 3	Average
Apr.12	2.12	1.93	1.53	1.86	2.24	2.37	2.00	2.20
Apr.19	2.08	2.03	2.18	2.10	4.01	3.54	4.12	3.89
Arp.26	1.82	3.06	2.42	2.43	3.33	3.48	2.71	3.17
May.3	3.68	2.62	2.54	2.95	3.20	3.21	3.48	3.30
May.10	1.83	4.90	2.16	2.96	4.81	5.15	9.44	6.47
May.17	2.57	2.78	2.13	2.49	6.63	5.03	4.16	5.27
Correlation	0.25	0.62	0.47	0.45	0.84	0.88	0.56	0.76
Multiple R	0.25	0.62	0.47	0.45	0.84	0.88	0.56	0.76
R Square	0.06	0.38	0.22	0.22	0.71	0.77	0.31	0.60
t-score	0.53	1.56	1.06	1.05	3.16	3.67	1.34	2.72
p-value	0.63	0.19	0.35	0.39	0.03	0.02	0.25	0.10

The correlation between root length and sown date is 0.45 while the correlation between shoot length and sown date is 0.76. This indicates that both growing measurements are positively related to the sown dates and the shoot length has stronger direct relationship than root length to the sown dates. For the variability in root length, the average value of 0.22 and in shoot length, the average was 0.6. However, replica 1 in root length and replica 3 in shoot length can be considered as outlier due to their difference from the other replicas. As for the p value, root length shows no statistical significance, with 3 replicas each are higher than the standard significance level of 0.1. In terms of shoot length, replica 1 and replica 2 showed statistical significance therefore we can say that shoot length and sown dates have better significant correlation than root length and sown dates.

During harvesting, there were 3 measurements that was taken place.

1. Number of pods per plant: Pods in the head of mustard that contains seeds.
2. Seed number per pod: Seeds that are located inside the pod.
3. Yield: measured in tons per hectare, it is a total weight of harvested mustard divided by unit area.

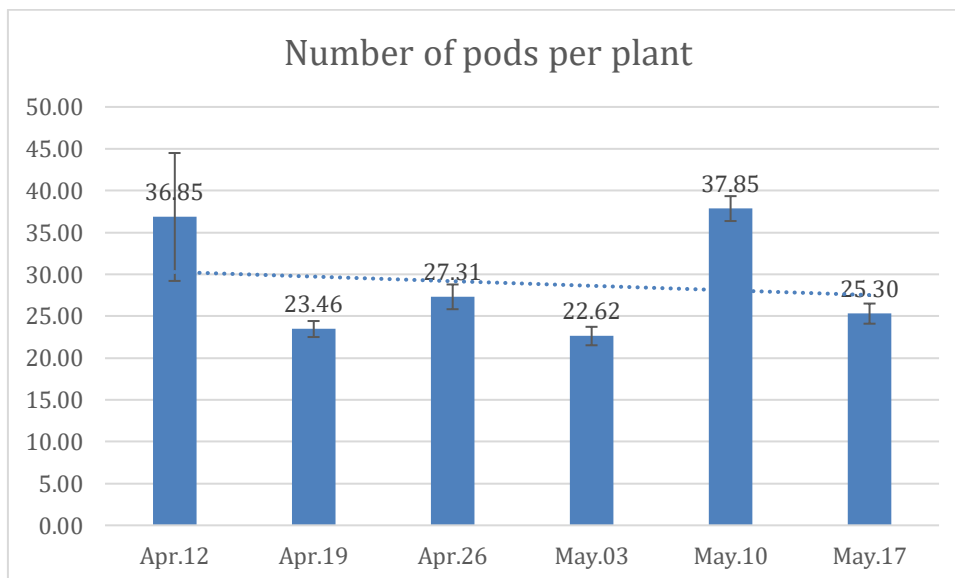


Figure 23 Number of pods per plant of mustard

While the highest number of pods per plant in mustard was from the crop that was sown in May 10th, the overall graph shows slight decrease. Although at April 12th sown crops had 2nd highest number of pods per plant, the error bar suggest that this value might be not precise due to its high variability. If we assume this data as outlier, we will be seeing a positive trendline from April 19th. The correlation coefficient of this data set was -0.15, which is an inverse relationship but shows weak linear relationship. With a p value of 0.77, the both correlation coefficient and p value suggest that the number of pods per plant is not statistically significantly correlated with sown dates.

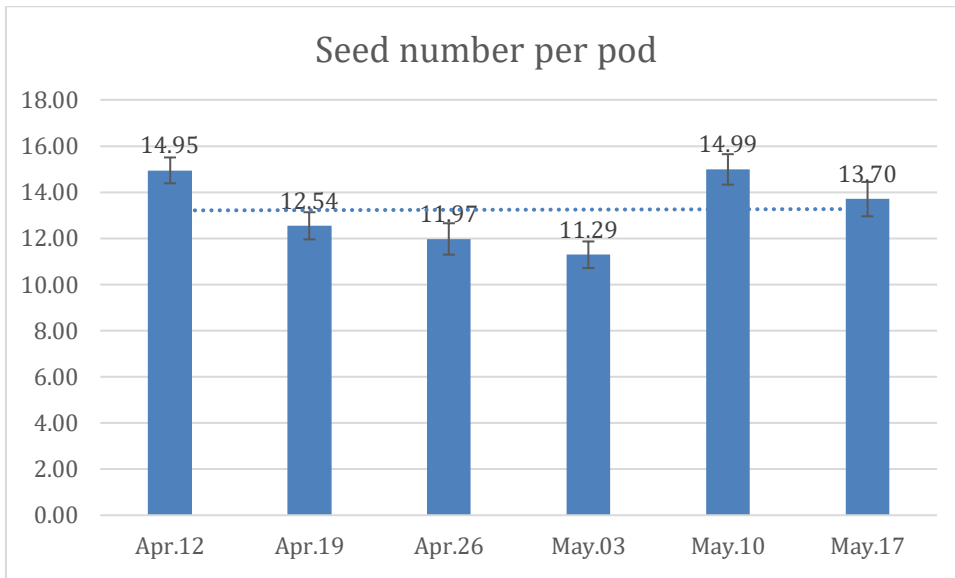


Figure 24 Seed number per pod of mustard

Similar with number of pods per plant, the seed number per pod was highest at May 10th and lowest at May 3rd. Unlike number of pods per plant, there are very few huge variabilities in error bars, suggesting that the values are more precise. Trendline can be seen has having low gradient, therefore suggesting that this is a negligible linear relationship. From the data, we can see that the correlation coefficient was 0.01, further supporting the weak linear relationship. Since the p value was 0.98, the conclusion should be that seed number per pod is not correlated to the sown dates using statistical significance.

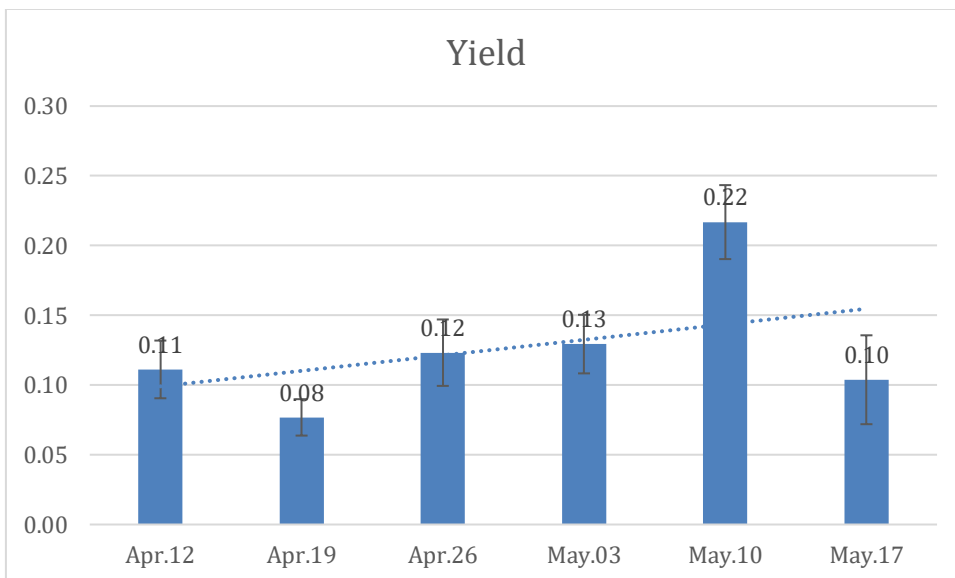


Figure 25 Yield of mustard

Unlike previous graphs, there is a clear positive relationship between yield and sown dates. Highest yield was obtained from the sown date of May 10th while the lowest yield was in April 19th. The error bars suggest that there is higher variability in dataset, making the graph less precise.

Correlation coefficient was 0.44 and the p value was 0.39. While the both significance coefficients were lower than previous measurements, it is still significantly not correlated if we assume the standard significant level of 0.05.

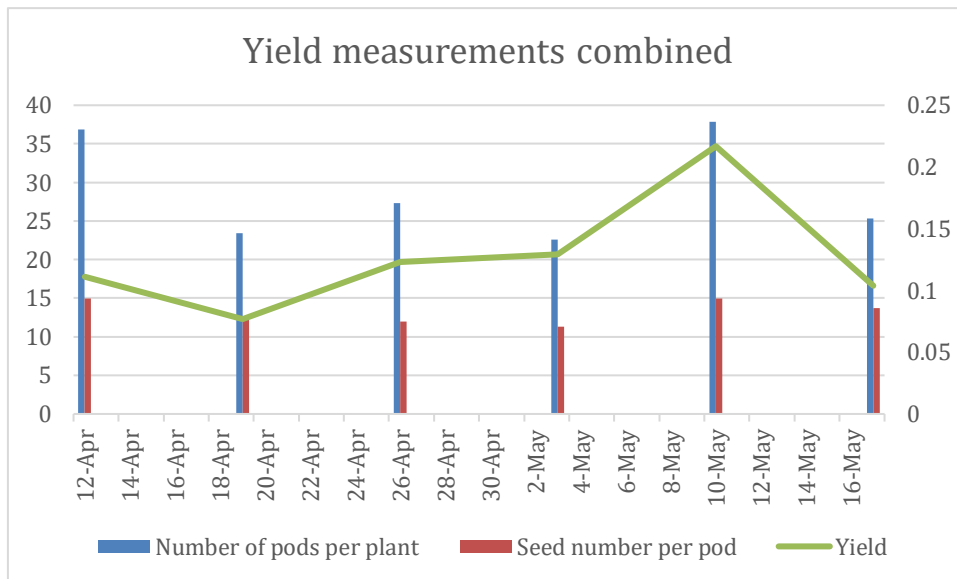


Figure 26 Yield measurements combined of mustard

From the combined graph, we can see that May 10th is the best date for mustard to be sown in term of yield while May 3rd is the worst date for mustard to be sown. Another point to observe is due to the high error bars and variability, the yield data from April 12th is not to be trusted with.

4.2 Barley

4.2.1 Germination

Number of germinated seeds per square meter shows that the highest number was from the date April 26th. Lowest number was at May 10th and the sudden drop in germination from May 3rd to May 10th shows an influence of external factors. Overall graph shows declining pattern with number of germinated seeds having a negatively gradient trendline. From the statistics, the average number of germinated seed and sown dates has a strong negative relationship, with the correlation coefficient of -0.7. P value from this coefficient was 0.13, which is lower than significance level of

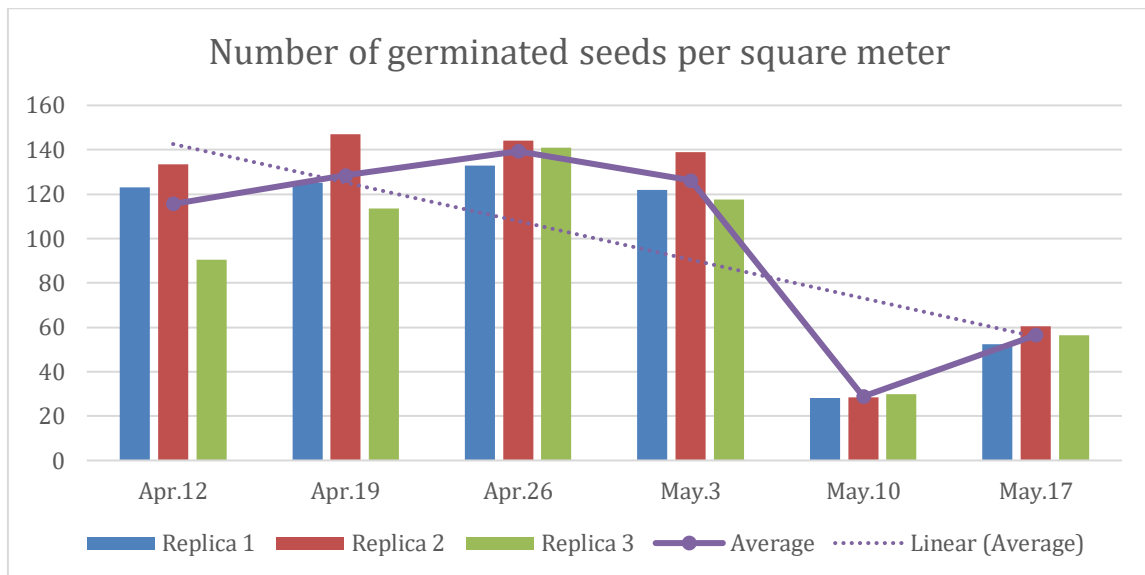


Figure 27 Number of germinated seeds per square meter of barley

Table 5 Statistical analysis of number of germinated seeds

Mustard	Replica 1	Replica 2	Replica 3	Average
Apr.12	123.00	133.50	90.50	115.67
Apr.19	125.00	147.00	113.50	128.50
Apr.26	133.00	144.00	141.00	139.33
May.3	122.00	139.00	117.50	126.17
May.10	28.00	28.50	30.00	28.83
May.17	52.50	60.50	56.50	56.50
Correlation	-0.78	-0.76	-0.57	-0.70
Multiple R	0.78	0.76	0.57	0.70
R Square	0.60	0.58	0.33	0.50
t-score	2.47	2.34	1.39	2.07
p-value	0.07	0.08	0.24	0.13

Each replica had a negative relationship with the sown dates, as evidenced by the negative correlation values. Since these values are lower than -0.5, it indicates strong correlation. For the R square, with the exception of replica 3 having only 0.33, other 2 replicas showed high R square value, meaning higher proportion of variability. P value are obtained from t score and although average value was higher than 0.1 therefore meaning it's not significant enough, replica 1 and replica 2 had p values lower than 0.1, meaning it can be said that the correlation between germinated seeds and sown dates is somewhat significant.

4.2.2 Growth factors

When we investigate the root and shoot length of the barley, we see the uprising values of shoot length as the time goes. In April 12th, the shoot length was at the lowest with 6.88 cm and it constantly increase to 17.87 cm with its highest height in the last sown date, May 17th. This shows that later sown dates are better for the shoot length. As for root length, the increasing interval is

not as much as the shoot length, however it is still increasing in small amount. With the lowest value in April 12th with 7.99 cm, it increased up until May 10th, where it was at its maximum value with 8.78cm.

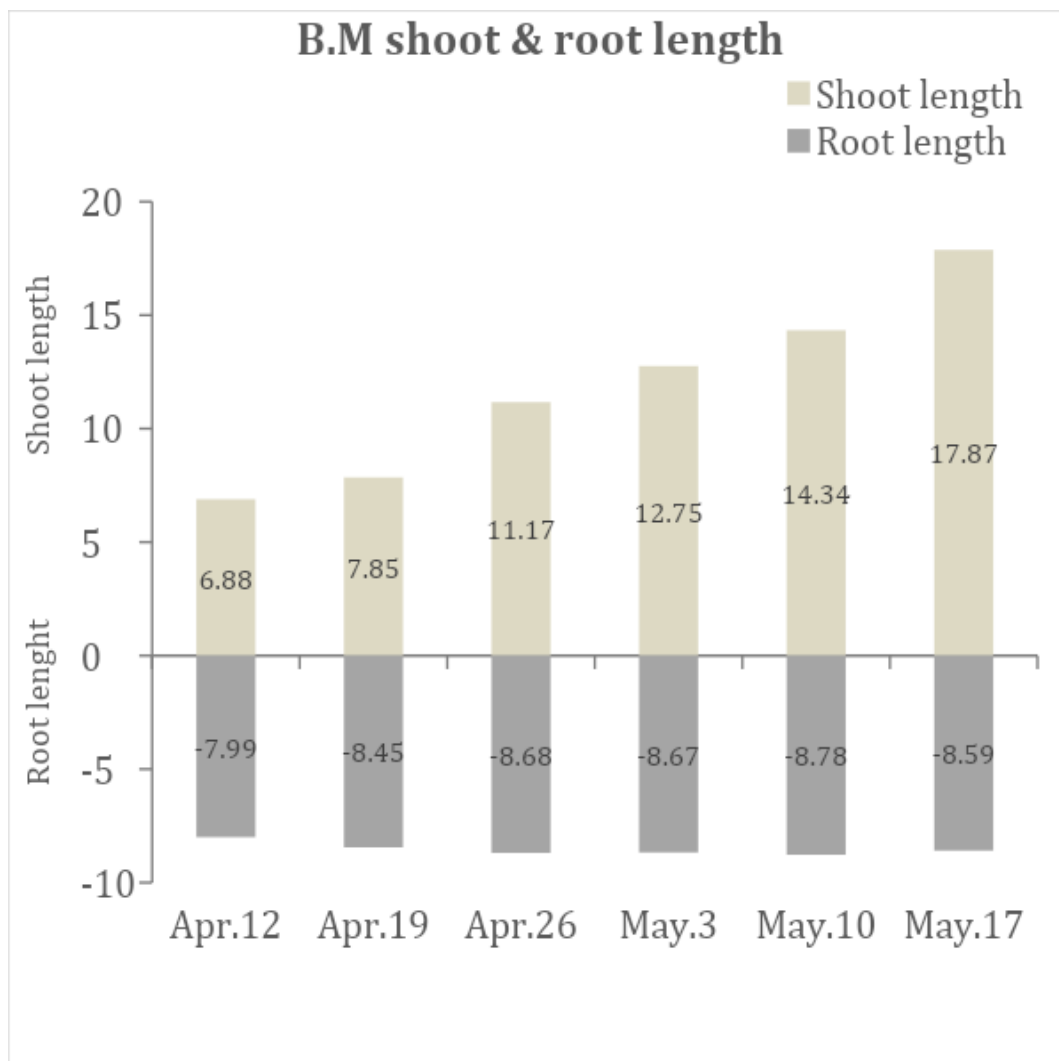


Figure 28 Shoot and root length of barley

Table 6 Statistical analysis of root and shoot length

	Root length				Shoot length			
	Replica 1	Replica 2	Replica 3	Average	Replica 1	Replica 2	Replica 3	Average
Apr.12	8.7	8.08	7.21	8.00	5.58	9.05	6.01	6.88
Apr.19	8.03	8.63	8.68	8.45	8.06	7.72	7.78	7.85
Apr.26	8.86	9.06	8.12	8.68	11.14	10.61	11.77	11.17
May.3	8.88	8.58	8.57	8.68	11.57	13.1	13.58	12.75
May.10	8.86	8.76	8.72	8.78	14.03	14.56	14.43	14.34
May.17	8.6	8.81	8.37	8.59	17.01	18.57	18.04	17.87
Correlation	0.45	0.50	0.52	0.49	0.88	0.83	0.86	0.86
Multiple R	0.45	0.50	0.52	0.49	0.88	0.83	0.86	0.86
R Square	0.20	0.25	0.27	0.24	0.77	0.69	0.75	0.73
t-score	1.00	1.14	1.22	1.12	3.67	2.96	3.44	3.36
p-value	0.37	0.32	0.29	0.33	0.02	0.04	0.03	0.03

The correlation between root length and sown date is 0.49 while the between the shoot length and sown date is 0.86. This shows that shoot length has strong correlation with the sown dates while root length had positive but not as strong correlation as shoot length. Both correlations favor that later sown dates are better for the growth factors. In terms of variability, the average value of 0.24 of root length vs average value of 0.73 of shoot length indicates that shoot length has 73% of variation that can be explained by sown dates while root length only has 24 %. P values for the root length is 0.33, which is higher than the significantly level (0.1), therefore we can say that the correlation between root length and sown date is not statistically significant. However, on the other hand, shoot length has a p value of 0.03, which is a strong evidence that supports the notion of shoot length and sown date being correlated.

4.2.3 Harvesting measurements

During harvesting period, there were 3 parameters that was accounted for.

1. Number of tillers
2. Yield
3. Seed weight

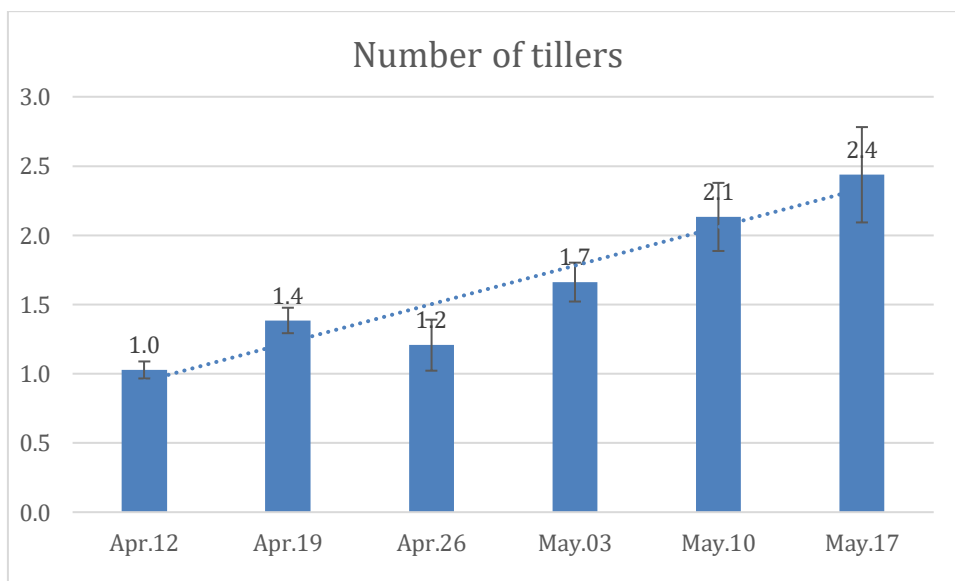


Figure 29 Number of tillers of barley

Trendline can be seen as uprising, upwards line indicating the strong positive relationship between sown dates and number of tillers. Lowest tillering was achieved from sown date of April 12th, while the highest tillering was observed at May 17th. This can be seen as later sowing dates, especially May dates have higher number of average tillers than April, suggesting that the sown dates must be after May. As for the statistical numbers, the correlation coefficient was 0.95, almost a perfect linear positive relationship. From this, the p value was 0.004, which satisfies 0.1 significance level, therefore the number of tillers and sown dates are statistically significantly strongly correlated.

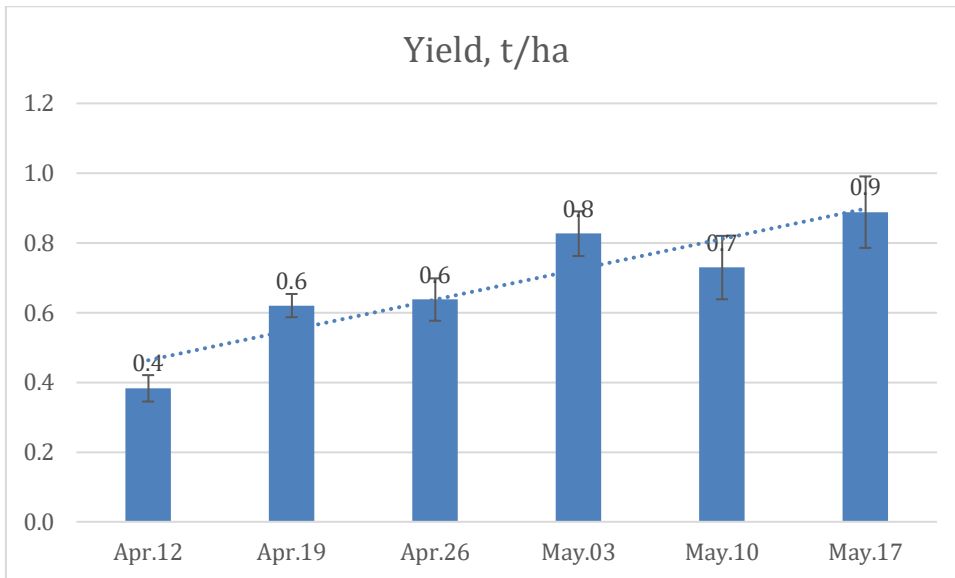


Figure 30 Yield of barley

Yield shows similar trendline as number of tillers. An uprising trendline strongly suggests positive relationship with the highest yield obtained from the May 17th sown date while the lowest yield was obtained from the April 12th sown date. This also support the notion of later sowing dates result in higher yield. Error bars suggest that the measurements are more precise with low variability and the correlation coefficient was 0.91 and p value was 0.013. Yield and sown dates are correlated statistically significant, with favoring later sown dates.

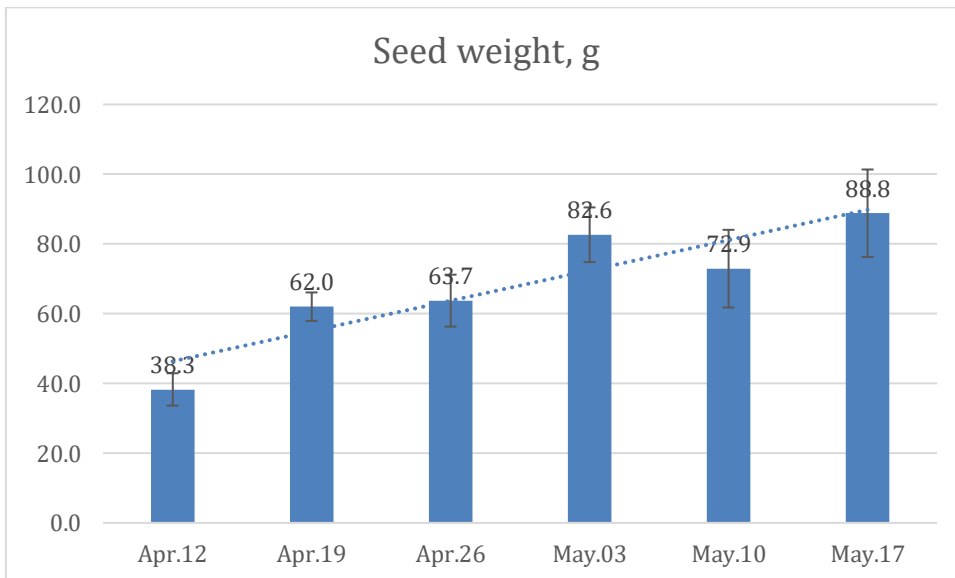


Figure 31 Seed weight of barley

For the seed weight, it is an important measure of yield as heavier seed weight results in more nutritional value. Similar to other yield measurements, the seed weight has a direct positive linear relationship with sown dates, later sown dates having more seed weight than earlier sown dates. Another thing to note is the error bars being longer, therefore making this dataset less precise. However, from the statistical calculations, the correlation coefficient was 0.91 and the p value was

0.013. It is safe to say that seed weight and sown dates are strongly correlated with statistics backing up.

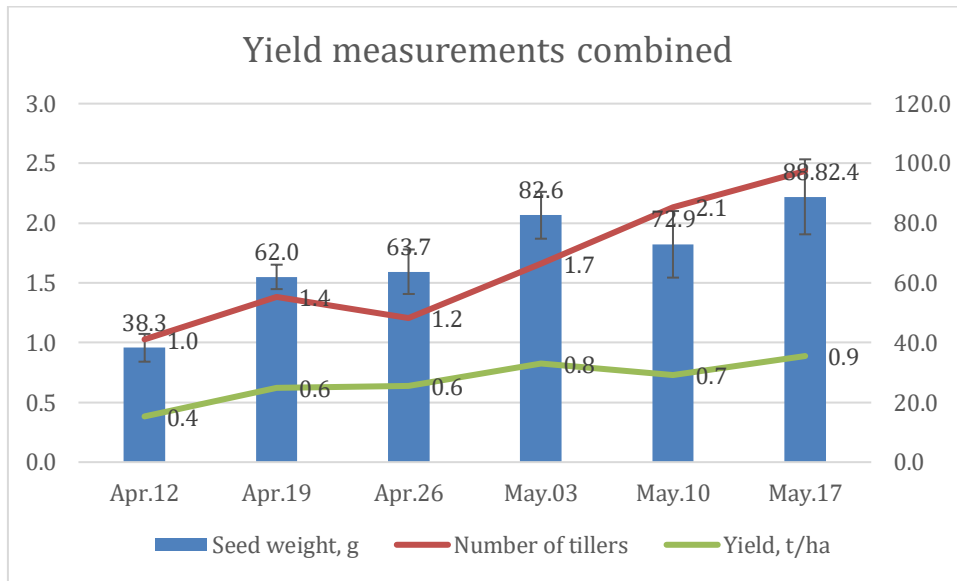


Figure 32 Yield measurement combined of barley

From the combined graph, we can say that every yield measurement has positive correlations with high coefficients and low p values therefore later sown dates are favorable for the yield of the barley with the best yield date of May 17th and the worst yield date of April 12th.

4.3 Wheat

4.3.1 Germination

Number of germinated seeds per square meter of the wheat shows an interesting pattern. Highest number of germinated seeds observed in April 19th while the lowest value was observed in May 17th. From April 19th to May 17th, it shows a decreasing trend therefore implying that earlier sown dates are better for the number of germinated seeds. However, sown date at April 12th had the 3rd lowest average, therefore the sown dates should be after April 12th. Other things to notice is that the huge variability in April 19th can be skewed as it has very high replica 2 but very lower replica 3 numbers.

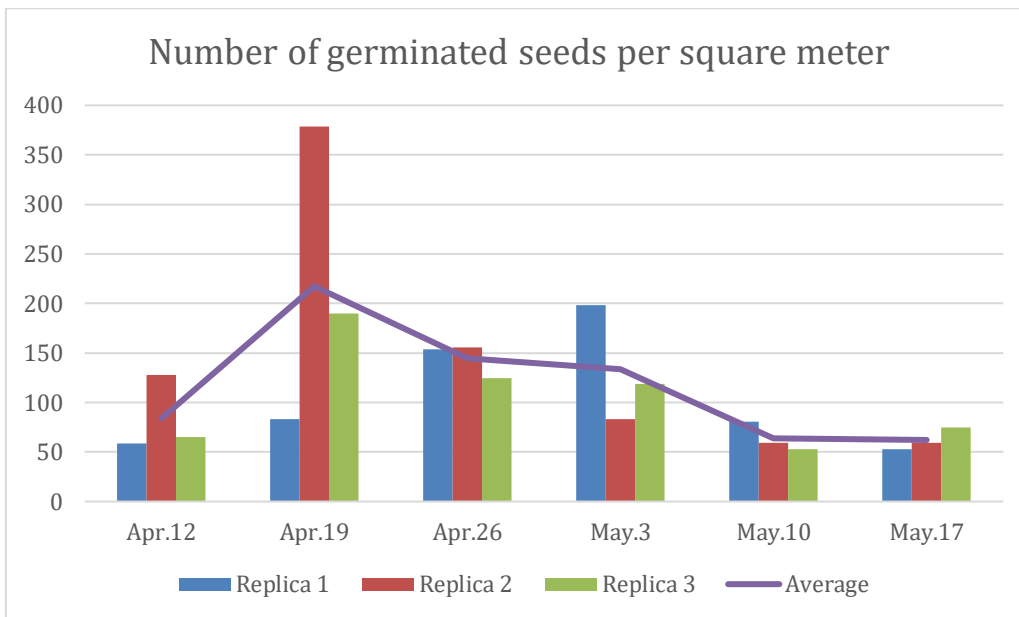


Figure 33 Number of germinated seeds per square meter of wheat

Table 7 Statistical analysis of number of germinated seeds

Mustard	Replica 1	Replica 2	Replica 3	Average
Apr.12	58.50	128.00	65.00	83.83
Apr.19	83.50	378.50	190.00	217.33
Apr.26	153.50	155.50	124.50	144.50
May.3	198.00	83.50	119.00	133.50
May.10	80.50	59.00	52.50	64.00
May.17	53.00	59.00	74.50	62.17
Correlation	0.01	-0.61	-0.39	-0.33
Multiple R	0.01	0.61	0.39	0.33
R Square	0.00	0.37	0.15	0.17
t-score	0.01	1.53	0.84	0.79
p-value	0.99	0.20	0.45	0.55

There are some differences between replicase in terms of statistical values. Replica 1 had a correlation coefficient of 0.01 other 2 replicase show a negative correlation. This directly affected the p value of each replica and averages. Therefore, since the average p value of 0.55 as well as other replicas are not lower than 0.1, the correlation between number of germinated seeds per square meter and sown dates are statistically insignificant.

4.3.2 Growth factors

From the data of root and shoot length, we can obtain the fact that shoot length has more correlation with sown date than root length. With the highest value of 19.61 cm from May 17th and the lowest value of 5.67cm in April 12th, we can say that later sown dates result in higher shoot length. On the other hand, highest root length was obtained from May 10th and shortest route length was obtained from the April 12th.

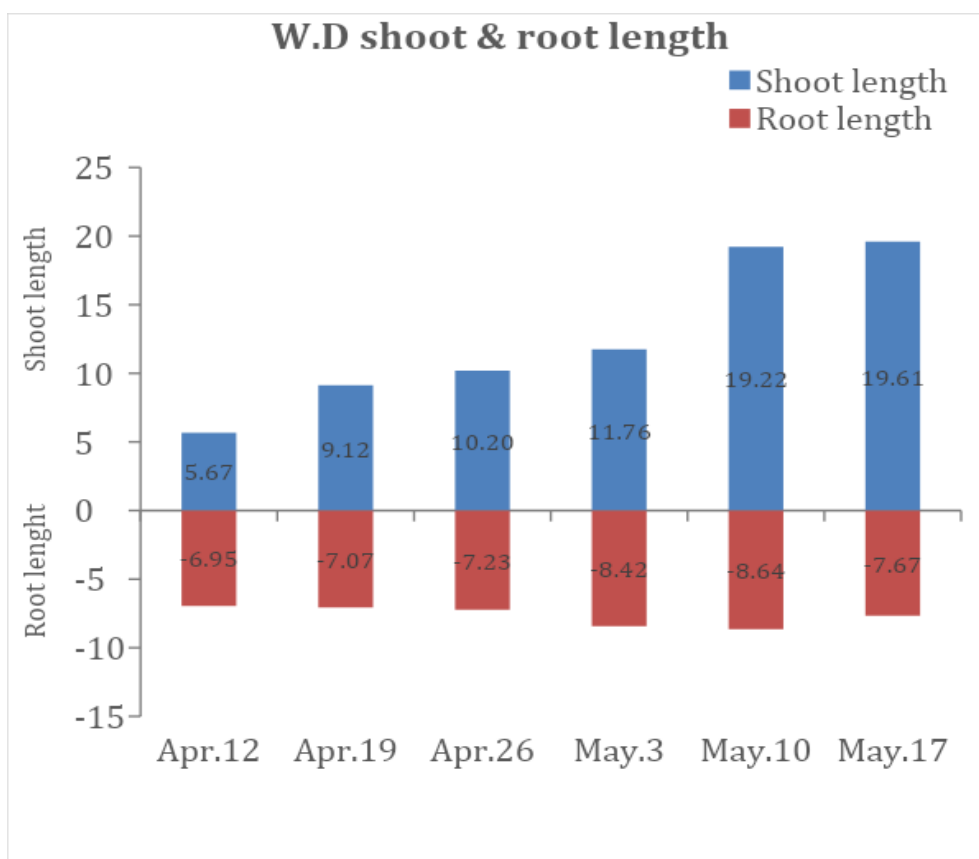


Figure 34 Shoot and root length of wheat

Table 8 Statistical analysis of root and shoot length

	Root length				Shoot length			
	Replica 1	Replica 2	Replica 3	Average	Replica 1	Replica 2	Replica 3	Average
Apr.12	6.65	6.85	7.34	6.95	5.53	6.04	5.43	5.67
Apr.19	5.73	7	8.49	7.07	8.94	9.2	9.22	9.12
Apr.26	7.28	7.25	7.15	7.23	11.08	10.07	9.47	10.21
May.3	8.6	8.84	7.81	8.42	10.28	12.49	12.51	11.76
May.10	7.9	8.71	9.32	8.64	21.41	19	17.26	19.22
May.17	8.98	7.55	6.49	7.67	19.01	21.58	18.27	19.62
Correlation	0.85	0.63	-0.06	0.71	0.90	0.97	0.98	0.96
Multiple R	0.85	0.63	0.06	0.51	0.90	0.97	0.98	0.95
R Square	0.73	0.40	0.00	0.38	0.81	0.95	0.96	0.91
t-score	3.26	1.62	0.12	1.67	4.19	8.29	9.49	7.33
p-value	0.03	0.18	0.91	0.37	0.01	0.001	0.001	0.01

From the statistical points, we can see that shoot length and sown dates are strongly correlated with the coefficient of average of 0.96. Although not as much, root length and sown dates are positively correlated with the coefficient of 0.71. However, an important thing to note is that replica 3 of the root length has a correlation of -0.06, which shows no correlation at all. Therefore, this might be an anomaly as other 5 replicas had a correlation value that is higher than 0.63.

As for the R square value, the root length has much lower average than shoot length, meaning it has more variability therefore less correlation than shoot length. For the p value, the root length has the average of 0.37 which is skewed by the much higher p value of 0.91. In replica 1 of root length, the p value is actually 0.03, which is significant for the significance level. On shoot length, the average value was 0.01 therefore shoot length is directly, positively correlated with the sown dates with high significance.

4.3.3 Harvesting measurement

During harvesting period, there were 3 parameters that was measured. There was an incident that lead to the disappearance of April 26th data therefore following graphs will show 5 points of sown dates.

1. Seed number per pod
2. Number of tillers
3. Yield

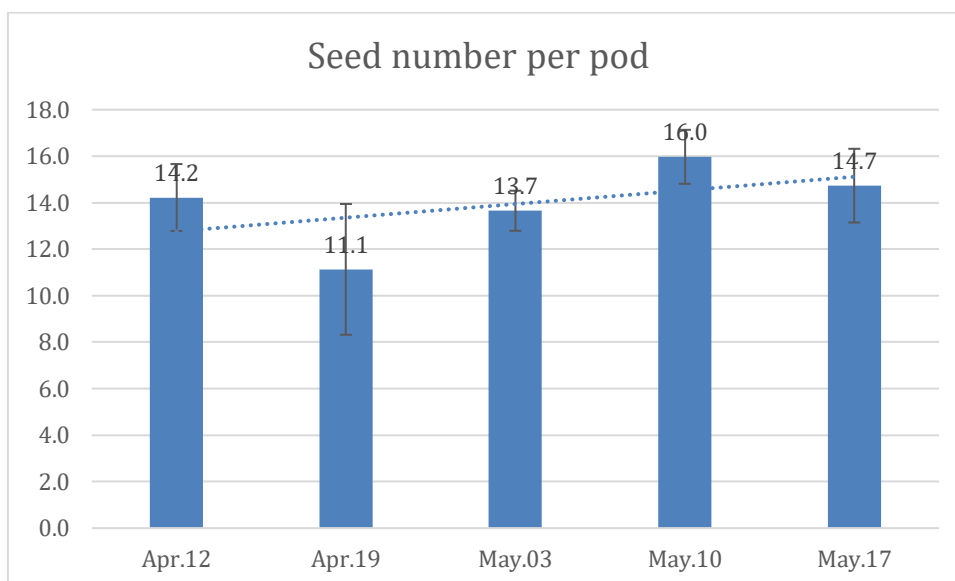


Figure 35 Seed number per pod of wheat

The highest seed number per pod was at May 10th while the lowest seed number per pod was at April 19th. Trendline shows an up-warding way therefore it could indicate that later sown dates are better for the seed number per pod of the wheat. With a correlation coefficient of 0.57 indicating not strong positive relationship and the p value of 0.301, it can be noted that seed number per pod and sown date doesn't have any correlation that is supported by the statistical significance.

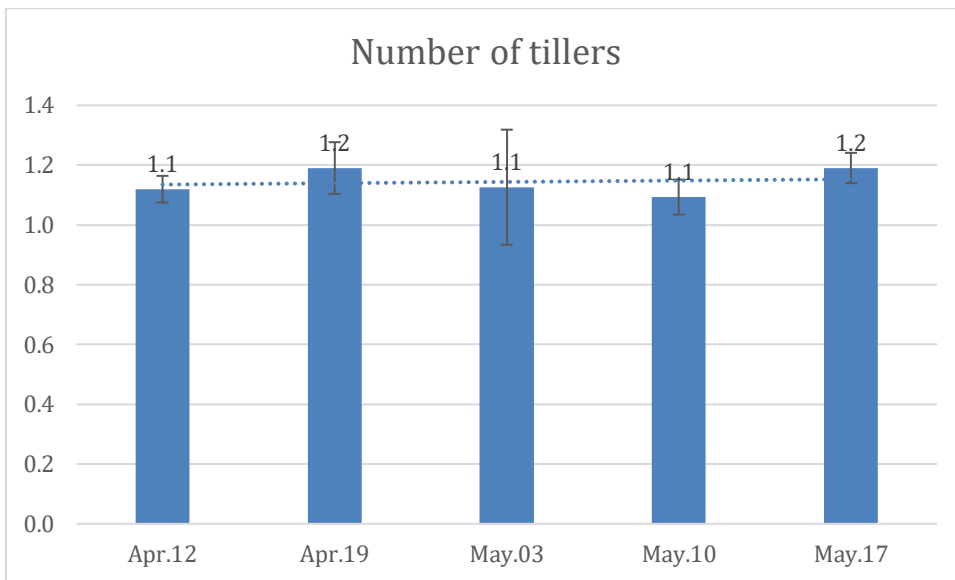


Figure 36 Number of tillers of wheat

Number of tillers, similar to number of seeds per pod, shows very little correlation with the sown date. With only 2 values of 1.1 and 1.2 in 5 sown dates, it can be said that the number of tillers is constant when sown during April to May. Also, the correlation coefficient was 0.06, sown dates and number of tillers do not correlate.

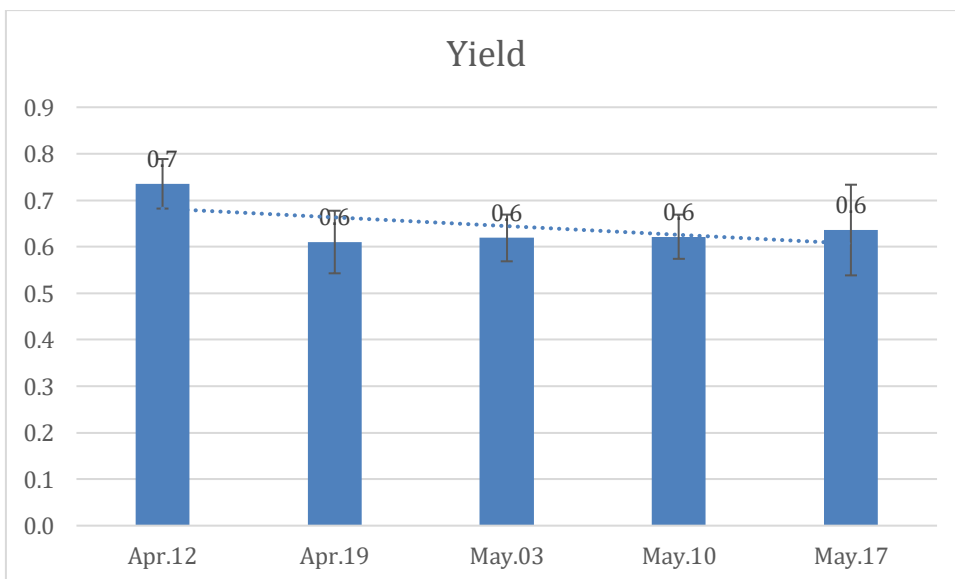


Figure 37 Yield of wheat

As for the yield, the highest obtained value was in April 12th and the rest of the date has the same amount of yield. Therefore, similar to number of tillers, sown date doesn't affect the yield parameters.

From the 3 parameters, we can see that sown date doesn't have any correlation with yield as it appears constant across dates.

4.4 Buckwheat

4.4.1 Germination

For the number of germinated seeds per square meter, buckwheat had an upwards trendline. With the highest average in May 20th and the lowest average in May 6th, it can be said that later sown dates are better for the germination of buckwheat seeds.

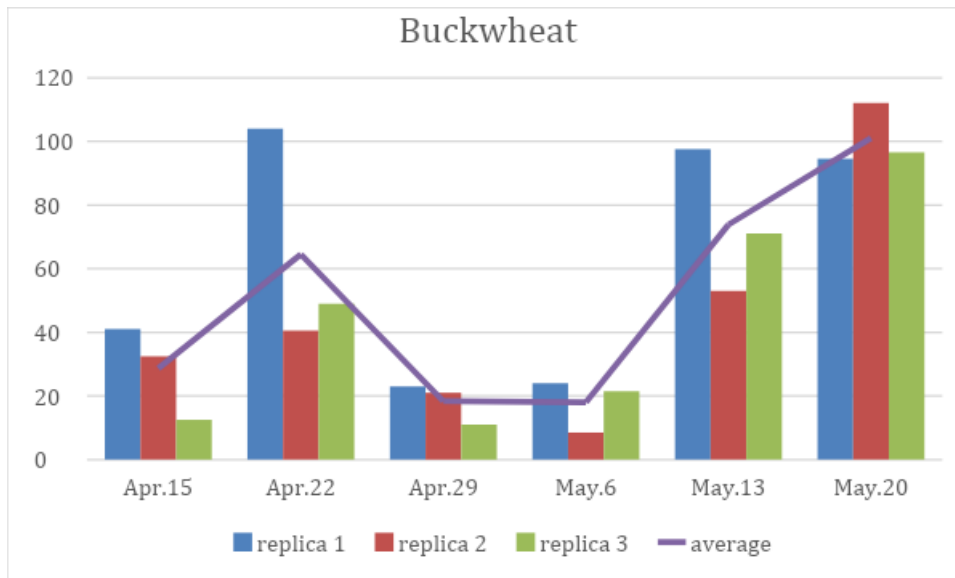


Figure 38 Number of germinated seeds per square meter

Table 9 Statistical analysis of number of germinated seeds

Mustard	Replica 1	Replica 2	Replica 3	Average
Apr.12	41.00	32.50	12.50	28.67
Apr.19	104.00	40.50	49.00	64.50
Apr.26	23.00	21.00	11.00	18.33
May.3	24.00	8.50	21.50	18.00
May.10	97.50	53.00	71.00	73.83
May.17	94.50	112.00	96.50	101.00
Correlation	0.34	0.62	0.76	0.57
Multiple R	0.34	0.62	0.76	0.57
R Square	0.12	0.38	0.58	0.36
t-score	0.73	1.58	2.34	1.55
p-value	0.50	0.19	0.08	0.26

From the statistical values, we can see that the average correlation is 0.57, which is a positive but not strong relationship. It means there is not enough evidence to support that sown dates and germination of seeds of buckwheat are correlated. With the p value of 0.26, it doesn't satisfy the significance level of 0.1, correlation between sown date and germinated seeds are insignificant.

4.4.2 Growth factor

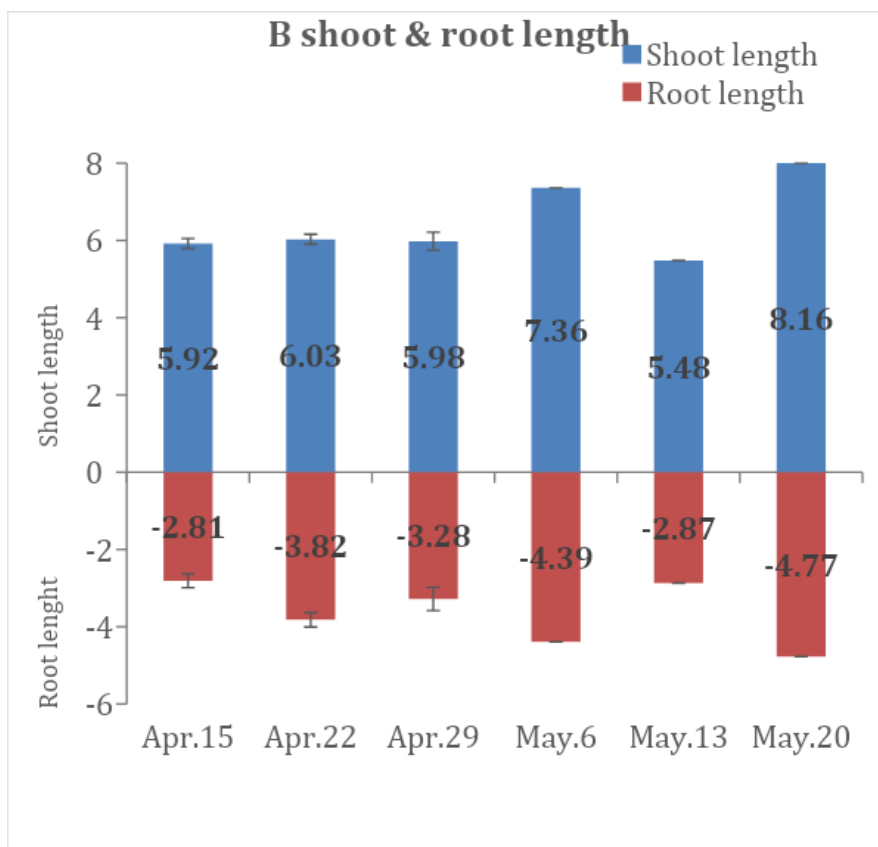


Figure 39 Shoot and root length of buckwheat

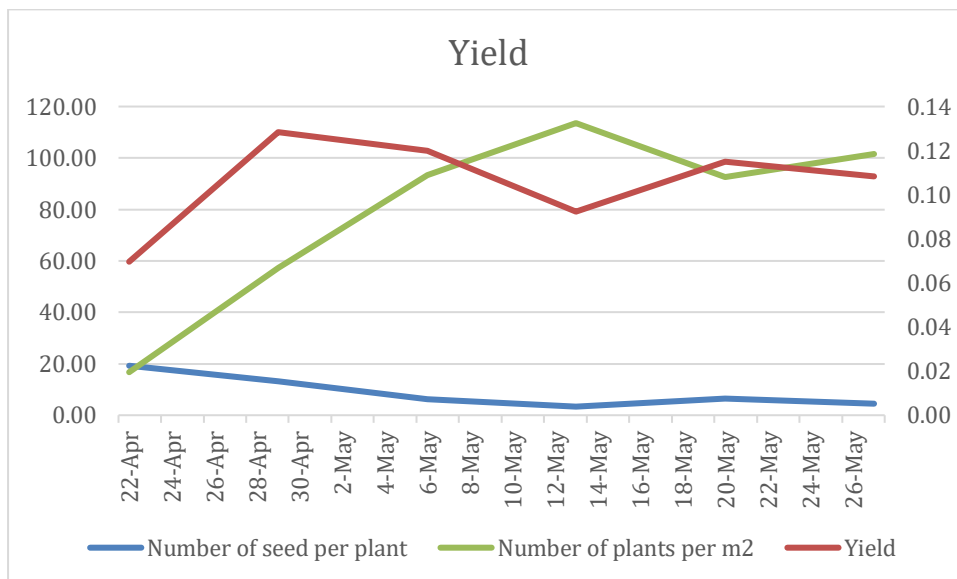
Table 10 Statistical analysis of shoot and root length

	Root length				Shoot length			
	Replica 1	Replica 2	Replica 3	Average	Replica 1	Replica 2	Replica 3	Average
Apr.15	3.05	2.03	2.57	2.55	6.58	5.66	5.53	5.92
Apr.22	4.71	3.52	3.23	3.82	6.02	6.11	5.96	6.03
Apr.29	2.78	3.14	3.92	3.28	6.04	6.14	5.76	5.98
May.6	4.38	4.39	4.41	4.39	7.23	6.87	7.99	7.36
May.3	3.22	2.71	2.68	2.87	4.61	5.71	6.10	5.47
May.20	4.17	4.10	6.04	4.77	8.60	8.55	7.32	8.16
Correlation	0.18	0.56	0.66	0.47	0.28	0.68	0.63	0.53
Multiple R	0.18	0.56	0.66	0.47	0.28	0.68	0.63	0.53
R Square	0.03	0.31	0.44	0.26	0.08	0.47	0.40	0.32
t-score	0.37	1.34	1.78	1.16	0.59	1.88	1.63	1.37
p-value	0.73	0.25	0.15	0.38	0.59	0.13	0.18	0.30

In terms of shoot and root length, the later sown date can be seen with more growth. For the shoot length, the lowest value is observed at May 13th while the highest value is observed at May 20th with 8.16cm. Same pattern observed with root length. Therefore, it can be seen that shoot length and root length of buckwheat can be grown better in later sown date. From the statistical

data, we can see that both root and shoot length has a positive weak cooperation coefficient with 0.47 and 0.53 respectively. With the p values of 0.38 and 0.3, we can note that root length and shoot length of buckwheat statistically insignificantly correlates with sown dates.

4.4.3 Yield measurements



For the yield measurements, 3 measurements were taken when harvesting buckwheat, number of seeds per plant, yield, and number of plants per meter squared. For the number of plants per meter squared, it shows an increase with time, with the best date being May 6th. For the Yield, with the exception of April 15th, all other dates have close ranged values, showing that it doesn't correlate with sown time. As for the number of seeds per plant, it shows a decrease from April 15th to May 6th, therefore it is best to plant the buckwheat in earlier dates. Correlation coefficient for Yield was 0.32 which is positive but it's a weak relationship. As for number of seeds per plant and number of plants per meter squared, the correlation coefficient was -0.85 and 0.82 respectively, suggesting that earlier sown dates are better for the number of seeds per plant but later sown dates are better for the number of plants per meter squared.

4.5 Pea

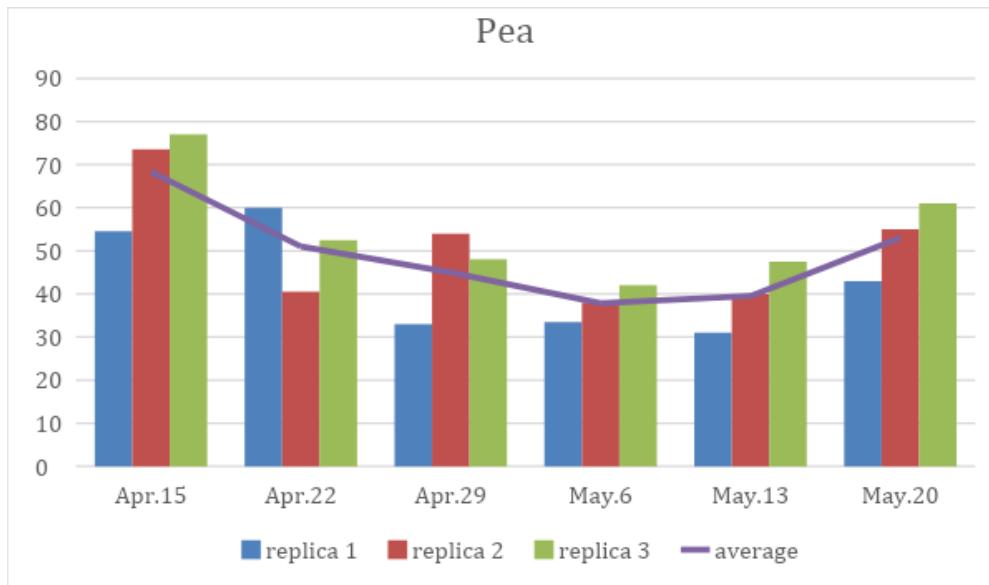


Figure 40 Number of germinated seeds per square meter

For the pea, it shows clear decrease from April 15th to May 6th in terms of germinated seeds. April 15th had the highest amount of germinated seeds with 68.3 while the May 6th had the lowest amount of germinated seeds with 37.8. This clearly indicates that early sown dates are better for the seeds of pea.

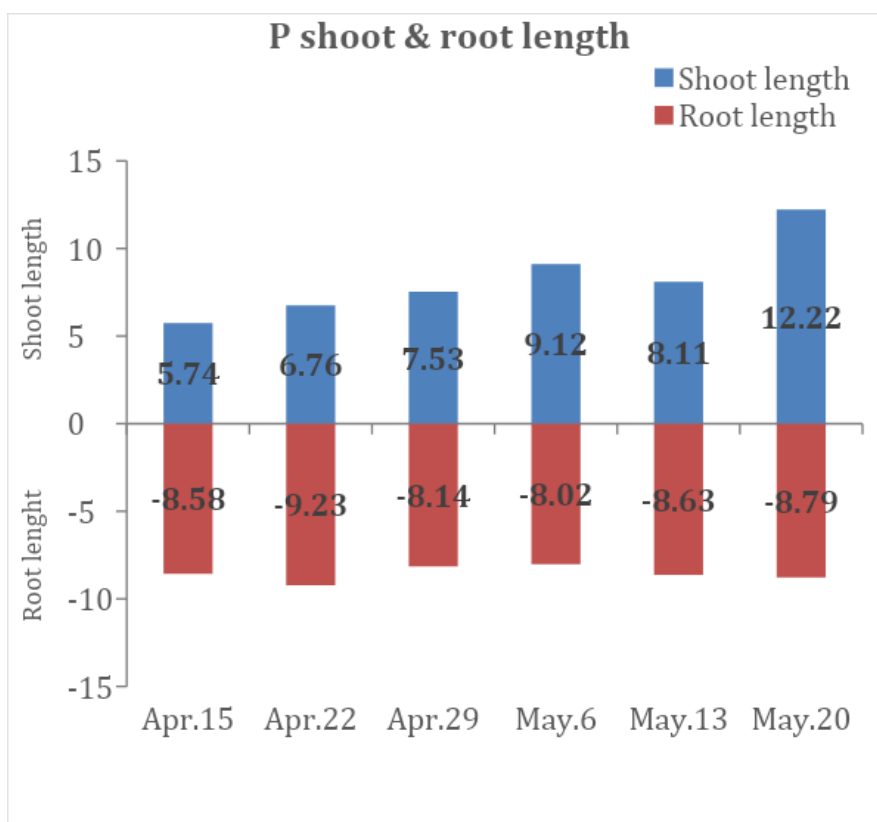


Figure 41 Root and shoot length of pea

For the shoot and root length, pea shoot length increases with time while root shoot length relatively stays the same. May 20th had the highest shoot length of 12.22cm while April 15th had the lowest shoot length with the value of 5.74cm. On the other end, root length shows relatively similar values across date, with the correlation value of 0.1. Therefore, with the respect to shoot length, it is better recommended to plant peas in later sown dates, around May 20th.

Table 11 statistical analysis of root and shoot length

	Root length				Shoot length			
	Replica 1	Replica 2	Replica 3	Average	Replica 1	Replica 2	Replica 3	Average
Apr.15	8.79	8.48	8.48	8.58	5.44	5.58	6.51	5.84
Apr.22	10.32	8.76	8.6	9.23	6.9	7.04	6.36	6.77
Apr.29	8.7	8.12	7.61	8.14	7.26	7.74	7.57	7.52
May.6	7.24	8.35	8.45	8.01	8.73	9.51	9.12	9.12
May.3	9.31	8.45	8.11	8.62	9.40	8.49	6.44	8.11
May.20	8.44	8.28	9.64	8.79	11.55	11.90	13.22	12.22
Correlation	-0.33	-0.42	0.41	-0.11	0.98	0.93	0.71	0.87
Multiple R	0.33	0.42	0.41	0.39	0.98	0.93	0.71	0.87
R Square	0.11	0.18	0.17	0.15	0.96	0.86	0.50	0.77
t-score	0.70	0.93	0.90	0.84	10.42	4.89	1.99	5.77
p-value	0.52	0.41	0.42	0.45	0.00	0.01	0.12	0.04

From the statistics, we can see that root length has a coefficient of -0.11 while the shoot length has a correlation of 0.87. Therefore, we can say that shoot length and sown dates are strongly correlated with positive gradient. From the p values, we can see that shoot length has a p value of 0.04 therefore it is statistically significant.

4.6 Oat

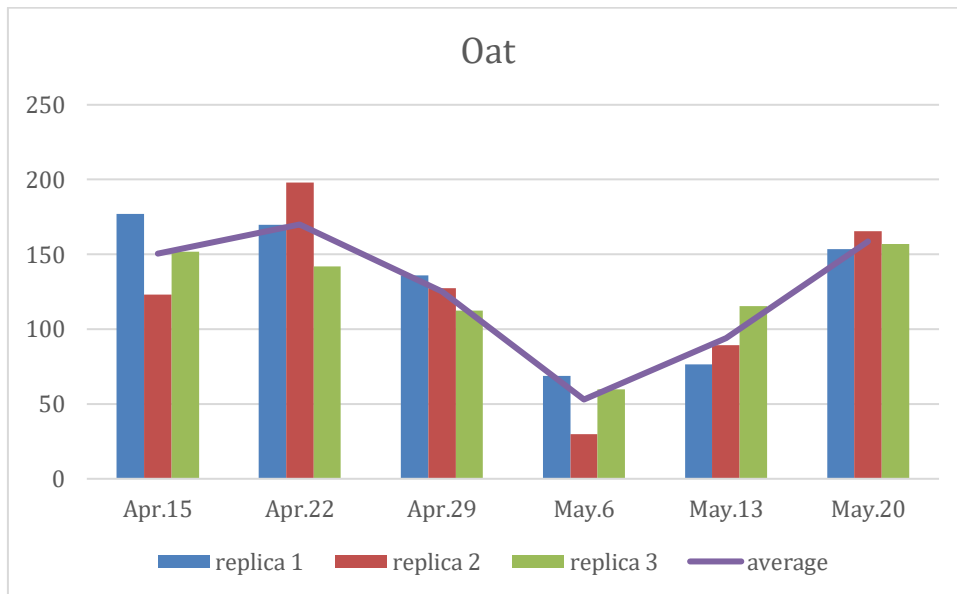


Figure 42 Germinated number of seeds per square meter

Oat had its highest value in April 22th and the lowest value in May 6th. From this, we can see that earlier sown dates favor the number of germinated seeds.

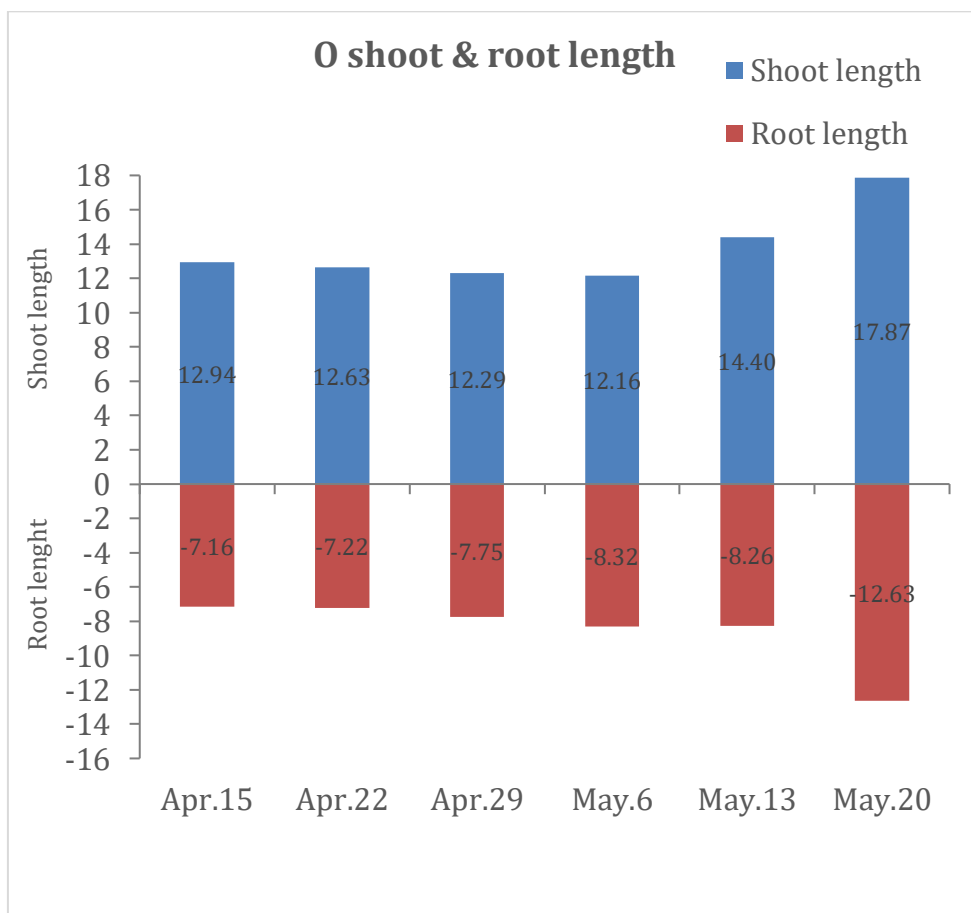


Figure 43 Shoot and root length of oat

For the shoot and root length, both parameters value the later sown date. Since there is a clear increase as time goes, we can say that sowing date is best for the oat. With the highest value of 17.87 in shoot length and 12.63 in root length, May 20th, is the best date when considering to sow an oat seed due to its growth.

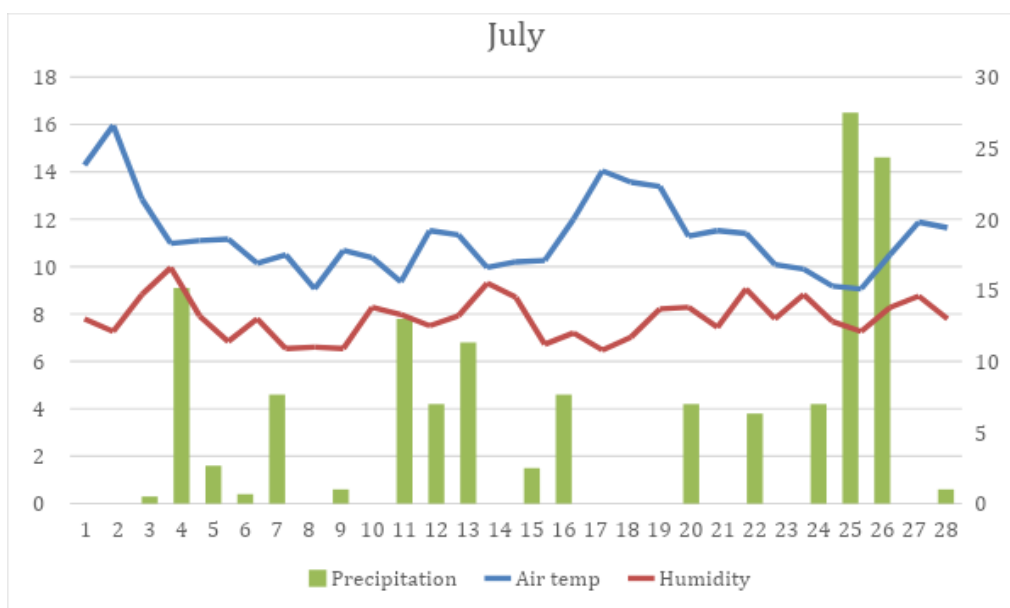
Table 12 Statistical analysis of root and shoot length

	Root length				Shoot length			
	Replica 1	Replica 2	Replica 3	Average	Replica 1	Replica 2	Replica 3	Average
Apr.15	7.26	6.94	7.29	7.16	12.32	13.69	12.881	12.96
Apr.22	7.56	7.15	6.96	7.22	13.77	11.88	12.22	12.62
Apr.29	7.4	9.48	6.35	7.74	12.29	11.85	12.74	12.29
May.6	8.66	8.92	7.39	8.32	12.39	11.95	12.13	12.16
May.3	8.84	8.14	7.80	8.26	13.83	16.09	13.27	14.40
May.20	13.50	15.00	9.40	12.63	17.70	18.10	17.80	17.87
Correlation	0.82	0.77	0.73	0.77	0.70	0.71	0.68	0.69
Multiple R	0.82	0.77	0.73	0.77	0.70	0.71	0.68	0.69
R Square	0.67	0.59	0.53	0.60	0.49	0.50	0.46	0.48
t-score	2.87	2.40	2.12	2.46	1.95	2.00	1.83	1.93
p-value	0.05	0.07	0.10	0.07	0.12	0.12	0.14	0.13

While root has more correlation than shoot length to sown date, it is not significantly enough. With the correlation value of 0.77, root length is strongly correlated and with p value of 0.07, it is significant. On the other hand, shoot length has a correlating of 0.69 but its p value of 0.13, more than 0.1 therefore it can't be considered as significant.

5 Recommendation and conclusion

Since this experiment was carried out with no integrated irrigation system, crops would be affected by the water stress. In the graph below, we can see that there are number of instances where there is no precipitation yet high air temperature and low air humidity. This causes water stress as well as increased rate of photosynthesis, transpiration and respiration. Because of this, root length and shoot length could be affected by these conditions therefore it is recommended to use irrigation system during days where there is no precipitation.



For the success germination		
Cultivars	Best sown date	Worst sown date
Mustard	April 19 th	May 10 th
Barley	April 26 th	May 10 th
Wheat	April 19 th	May 17 th
Buckwheat	May 20 th	May 6 th
Pea	April 15 th	May 6 th
Oat	April 22 nd	May 6 th

We can conclude that earlier sown date results in better number of successful germinations for every selected crop except buckwheat.

For the growth factors		
Cultivars	Best sown date	Worst sown date
Mustard	May 10 th	April 12 th
Barley	May 17 th	April 12 th
Wheat	May 10 th	April 12 th
Buckwheat	May 20 th	May 13 th
Pea	May 20 th	April 15 th
May 20 th	April 22 nd	April 22 nd

For the growth parameters, later sown dates result in more growth with the buckwheat being exception.

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