OnLine Journal of Biological Sciences

Original Research Paper

Influence of Mineral Fertilizers and Methods of Basic Tillage on the Yield and Oil Content of Sunflower

[1]Beybit Nasiyev and [2]Aida Dukeyeva

[1]*Zhangir khan West Kazakhstan Agrarian-Technical University, Kazakhstan*
[2]*Kostanai Engineering and Economic University named after M.v. Dulatov, Kazakhstan*

Article history
Received: 14-02-2023
Revised: 28-04-2023
Accepted: 08-05-2023

Corresponding Author:
Beybit Nasiyev
Zhangir khan West Kazakhstan Agrarian-Technical University, Kazakhstan
Email: veivit.66@mail.ru

Abstract: The purpose of the study was to evaluate the influence of mineral fertilizers and methods of basic tillage on the yield and oil content of sunflowers in the north of Kazakhstan. The experiment was conducted in the agricultural experimental Station Zarechnoye limited liability partnership with southern thin chernozem soils. Records and observations of the growth and development of sunflowers were carried out using modern methodological recommendations. The used agricultural technique of sunflower cultivation in the experiments was the one recommended for the study area. The authors studied new sunflower hybrids and different variants for the use of mineral fertilizers and methods of basic tillage. The paper concludes that it is important to use new sunflower hybrids Sumatra, Suzuka and Sumiko which achieve yields at the level of 1.34-1.46 c/ha with an oil content of 48.52-48.88%, which is the scientific novelty of the study. The combined use of mineral fertilizers according to the scheme $N_{40}P_{40}$ in the autumn + $N_{20}P_{20}$ in spring when sowing + $N_{10}P_{10}$ fertilizing in the conditions of the study zone increased the yield and harvest of sunflower oil to 1.34 and 0.65 t/ha. The no-till technique improved the biometric and productive yield indicators. In this variant, a high yield of sunflower was obtained (1.31 t/ha) with a high oil content (48.49%) and a higher oil yield of 0.63 t/ha was provided. These improvements in the quality and productivity of sunflower as the main oilseed crop are of significant importance for food security and sustainable agriculture in Northern Kazakhstan.

Keywords: Hybrids, Mineral Fertilizers, Tillage, Sunflower, Oil Harvesting

Introduction

After soybeans, peanuts and rapeseed, sunflower oil is the fourth most important vegetable oil in world trade with an annual sunflower production of about 18 million t and a sown area of more than 47 million ha. Since sunflower is relatively resistant to drought and effectively uses soil nutrients due to a well-developed and deeply penetrating root system, it is usually grown in arid and semi-arid countries (Sher *et al*., 2022).

According to the Ministry of Agriculture of Kazakhstan, in 2022, the acreage under sunflowers increased to 1 million ha and farmers threshed about 1.2 million t of sunflower seed, which is almost 2 times more than last year's figures (ElDala.kz, 2022).

Globally, sunflower is mainly grown to produce oil. The oil concentration (usually expressed as a percentage of the dry weight of seeds) mainly determines the industrial yield of grain. Accordingly, both the seed yield and the percentage of oil are important for producers to maximize gross income (Sher *et al*., 2022).

To increase the yield of sunflowers, it is important to improve the agricultural technique of this crop by selecting more adapted hybrids for the agro-climatic zone of crop cultivation. It is very important to regulate the feeding regime through mineral fertilizers, as well as the selection of optimal methods of basic tillage for sunflower crops (Nasiyev and Yessenguzhina, 2019; Nasiyev *et al*., 2022a).

One of the factors of low sunflower yield is the incorrect selection of hybrids for cultivation in risky farming zones (Ali *et al*., 2013). The choice of hybrid greatly affects the production of sunflowers. When choosing a hybrid, it is necessary to carefully consider the seed yield potential, oil content, oil composition, maturity, stem strength and disease resistance (Sarwar *et al*., 2013). Almost all seeds of hybrid sunflowers are imported and due to various agroecological conditions of their development, evaluation and production, the full potential of yield is not achieved in our climatic conditions. In addition, there is always a potential danger and the threat of the emergence of new noxious insects and diseases. All this requires the cultivation of well-adapted, high-yielding sunflower genotypes in local agroecological conditions (Khokhar *et al*., 2006; Hussain *et al*., 2016). Sunflower hybrids differ significantly in morphological characteristics and indicators related to yield. A larger number of leaves in the hybrid leads to the development of the most effective vegetation cover, which enhances the interception of photosynthetically active radiation, reduces the emergence of weeds by creating shade (Araus and Cairns, 2014) and improves grain separation, which leads to better crop growth and yield (Sher *et al*., 2022).

As shown at the global level, many factors, such as weeds and water scarcity, can lead to significant losses in the sunflower harvest and, consequently, the cultivation of the most suitable hybrids is of great importance (Papatheohari *et al*., 2016; Martirosyan *et al*., 2022; Zhao *et al*., 2022).

Sunflower has a wide adaptive environment and requires very sunny areas, but in their growth, the plants are not affected by photoperiodism. Inorganic components of fertilizers, such as Nitrogen, Phosphorus and potassium (NPK), are essential nutrients for plant growth and increasing sunflower yield (Handayati and Sihombing, 2019). Balanced fertilizers play an important role in providing the nutrients necessary to achieve maximum sunflower growth (Patil *et al*., 2009). The level of NPK fertilizer affects not only the vegetative mass of the plant but also the yield of the sunflower (Yuniza, 2018). The amount of Nitrogen (N) and Potassium (K) had a significant effect on plant height, biological yield, seed yield and oil content in seeds (Mollashahi *et al*., 2013). The addition of N and Phosphorus (P) also contributed to the growth and yield. When applying N fertilizers at the rate of 60 kg ha 1, the highest yield of seeds and oil was obtained (Osman and Awed, 2010). In studies with 200 kg/ha 1 N fertilizers, an increase in the maximum amount of filled seeds, oil and protein content was noted (Ghani *et al*., 2000; Ahmad *et al*., 2018).

However, scientific research on various schemes for the use of mineral fertilizers in the conditions of Northern Kazakhstan is still not sufficient, which led to the inclusion of this issue in the design of the study.

The relationship between crop cultivation and tillage plays an important role in agricultural production. Soils under conventional tillage have a lower bulk density and, consequently, a higher total porosity in the arable layer than in the absence of tillage (Sessiz *et al*., 2008; Nasiyev *et al*., 2020).

The no-till technique improves the chemical, physical and biological characteristics of the soil, contributing to an increase in stable productivity, as a result of which it becomes an economical method of reducing production costs by reducing energy losses and saving labor, as well as saving time required for soil preparation (Lipiec *et al*., 2006; Whish and Bell, 2008). In addition, such tillage technology contributes to the accumulation of moisture and organic matter and protects the soil from rain and wind erosion (Lopez *et al*., 2003; Lipiec *et al*., 2006). This method also prevents the germination of weed seeds in the soil (therefore, the density and number of weeds in the field are reduced). The use of conventional plowing of the soil, on the contrary, disrupts the dormant state of seeds and provokes them to germinate, which can negatively affect the growth and development of the plant, as well as yield (Hammood, 2018). The competition for moisture and nutrients is manifested most clearly in the first stages of the development of the cultivated plant, which may further affect the yield (Mohammed *et al*., 2019).

In studies conducted in Pakistan, India, Argentina and China, better soil characteristics (Wasaya *et al*., 2017; Sher *et al*., 2021) and sunflower yields were observed with conservation tillage compared to other tillage methods (Wang *et al*., 2017; Sher *et al*., 2018; Paul *et al*., 2020). As noted by Nardón *et al*. (2021) in the conditions of the Provincia de Buenos Aires, Argentina, sunflower yields and gross income were the highest with the no-till technique (3.16 mg·ha 1 and 902 USD·ha 1).

Hence, it is concluded that conservation tillage, in other words, the no-till technique, can increase the yield of sunflowers with low moisture availability. Thus, to increase the yield of sunflowers in areas with lower moisture capacity, conservation tillage is necessary.

Purpose of the Study

The purpose of the study was to evaluate the influence of mineral fertilizers and methods of basic tillage on the yield and oil content of sunflowers in the north of Kazakhstan.

Materials and Methods

Study Design and Stages of the Study

To achieve this goal, in 2020-2022, we conducted field experiments according to the design indicated in Tables 1-3 at the agricultural experimental station Zarechnoye Limited Liability Partnership (LLP) (Republic of Kazakhstan, Kostanay Region, Kostanay district, Zarechnoye village).

Table 1: Design of a field experiment on the selection of sunflower hybrids optimal in yield and quality for Northern Kazakhstan

No.	Variants of sunflower hybrids
1	Pioner (control)
2	Tristan
3	Sumatra
4	Suzuka
5	Sumiko

Table 2: Design of a field experiment on the study of the effects of mineral fertilizers on the yield and oil content of sunflowers in the conditions of the Kostanay Region

No.	Mineral fertilizer variants
1.	$N_{40}P_{40}$ background in the autumn + $N_{10}P_{10}$ in spring when sowing (control)
2	$N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing
3	$N_{40}P_{40}$ background in the autumn + $N_{30}P_{30}$ in spring when sowing
4	$N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing + $N_{10}P_{10}$ as a top dressing

Table 3: Design of a field experiment on the comparative study of methods of basic tillage for sunflower crops in the conditions of the Kostanay Region

No.	Basic tillage variants
1	Plowing (control)
2	No-till

The repetition of the experiment was fourfold; the plots were placed systematically. The acreage of plots was 53.2 m^2 and the accounting area was 50.4 m^2.

The length of each plot was 10 m and the width was 5.32 m. Additionally, guard plots with a length of 2 m and a width of 5 m were established.

The repetition of the experiment was fourfold; the plots were placed systematically. The acreage of plots was 53.2 m^2 and the accounting area was 50.4 m^2.

The length of each plot was 10 m and the width was 5.32 m. Additionally, guard plots with a length of 2 m and a width of 5 m were established.

The repetition of the experiment was fourfold; the plots were placed systematically. The acreage of plots was 53.2 m^2 and the accounting area was 50.4 m^2.

The length of each plot was 10 m and the width was 5.32 m. Additionally, guard plots with a length of 2 m and a width of 5 m were established.

The distance between each experimental plot was 10 m. The experimental design corresponded to the requirements of the current methods (Fedin, 2017).

The soil of the experimental site was southern thin chernozem in combination with alkali soils up to 10%. The thickness of the humus horizon (A + B) was 41-45 cm. Soil bubbling from HCl was observed from 85 cm, as well as the release of carbonates from the same depth. The humus content was 3.0-3.2%. The soil of the experimental plot in a layer of 0-20 cm contained 0.15-0.16% of gross N and 0.10-0.13% of P.

Stages of the Study

During the experiments, we carried out phenological observations, biometric measurements and laboratory analyses to determine the quality of sunflower yield according to accepted modern methods (Fedin, 2017).

The organization of observations of the onset of phenological phases, accounting for the growth and development (height, density of crops, crop structure) of sunflowers was carried out according to the methodological recommendations (Fedin, 2017). Considering phenology allowed us to determine the onset of the main phases of crop development, especially the time of full flowering with different technologies, the duration of flowering and physiological maturation since the success of harvesting depended on it.

In the study, the main phases of sunflower growth and development were established, namely, seedlings, three-four leaves, calathid formation, flowering and maturation.

The study of growth dynamics (height) allowed us to determine the period of the most intensive growth. The height of sunflower plants was determined in 10 sites of the plot in two non-contiguous repetitions of the experiment.

The density of seedlings and the number of plants preserved for harvesting were determined by counting seedlings and sunflower plants before harvesting on four permanent sites in two non-adjacent repetitions of the experiment. The structure of the sunflower crop was determined by analyzing 10 plants from the plot into their parts. The oil content in sunflower seeds was determined by the extraction method of extracting crude fat from seeds with an appropriate solvent in a Soxhlet apparatus.

Agricultural Technique in Experiments

The agricultural technique in the experiment was the one adopted for the Kostanay Region. The preceding crop was wheat. In the autumn, plowing was carried out with a PLN 5-35 plow to a depth of 27-30 cm. In spring, to level the soil surface and leave moisture in the soil, harrowing and mechanical pre-sowing tillage was carried out to the depth of seed embedding. Before the emergence of sunflower seedlings in the spring, the soil glyphosate containing herbicide Roundup (2 l/ha) was introduced.

Sowing was carried out with a SUPN-8 seeder with a row spacing of 70 cm, in optimal time. Sowing date: May 17. The seeding rate of hydrides was 50 thousand germinating seeds per 1 ha and the depth of seed laying was 6-8 cm.

NH_4NO_3 (ammonium nitrate) and $Ca(H_2PO_4)_2$ (double superphosphate) were used as mineral fertilizers. In experiments 1 and 3, mineral fertilizers were applied at a dose of $N_{40}P_{40}$ in the autumn for the main treatment and $N_{20}P_{20}$ in the spring for sowing. We studied the Pioner sunflower hybrid with a seeding rate of 50 thousand germinating seeds per 1 ha.

In experiment 3, plowing with a PLN 5-35 plow to a depth of 27-30 cm was carried out for the control variant in the autumn. In the variant of direct sowing of sunflower under the preceding wheat, mechanical treatments of the soil were not carried out and a systematic herbicide was used before direct sowing.

In all three experiments, sunflower yield was considered by the method of continuous threshing with a Sampo 130 combined harvester. Yields were reduced to standard humidity (10%) and purity (100%).

Data Analysis

The obtained scientific data were statistically processed by the method of one-factor variance analysis (Dospekhov, 2018).

Results

Weather Conditions

The growth and development of sunflowers were significantly influenced by the prevailing weather conditions of the growing season (Table 4).

As the weather data show, of all the studied agricultural years, the conditions of 2022 were the most favorable for the formation of higher yields with high sunflower oil content.

During the period of germination (May), the most favorable regime in terms of humidity and temperature was formed in 2020. Precipitation in May in the amount of 80.6 mm contributed to the formation of even sunflower stands.

The most critical period in terms of moisture for sunflowers is the period of calathid formation and flowering, i.e., July of the calendar year. Therefore, the uniform precipitation that fell in July 2022 in the amount of 81.2 mm at an optimal temperature regime of 21.6°C contributed to the formation of a higher yield of sunflowers. In 2022, the precipitation level for July exceeded the long-term level by 25.2 mm.

In the conditions of 2021, precipitation in the amount of 103.5 mm fell after the sunflower flowering phase (47.5 mm more than the long-term level), so this crop almost did not use the specified amount of atmospheric moisture.

In 2020, during the calathid formation and flowering of the sunflower, i.e., in July, only 17.4 mm of precipitation fell against the background of high temperatures (23.3°C), which significantly reduced the productivity and quality indicators of the sunflower.

Comparative Productivity of Sunflower Hybrids

To select more productive modern hybrids in terms of yield and oil content, as well as the ones optimally using the bioclimatic resources of the zone of interest, we established a field experiment. As the research data for 2020-2022 showed, the studied modern sunflower hybrids differed among themselves in terms of growth and development, as well as the yield and quality of oilseeds.

On average, for 3 years (2020-2022), the new hybrids Sumatra, Suzuka and Sumiko were distinguished by the highest field germination. In spring, during the period of full germination, the field germination of these hybrids was 88.24-88.91% with the number of seedlings of 44.12-44.45 thousand plants per 1 ha.

In the control variant (Pioner hybrid) and the variant of the Tristan hybrid, the plant density was determined within 43.66-43.63 thousand plants per 1 ha of sowing, which is less than 0.79-0.82 thousand plants per 1 ha compared to the hybrids mentioned above. That means that the Pioner and Tristan hybrids had less field germination compared to Sumatra, Suzuka and Sumiko hybrids by 1.59-1.66%.

It should be noted that the highest germination of seeds of the studied hybrids was established in 2020, with the highest precipitation in May (80.6 mm) and at an air temperature of 17.2°C.

The most important indicator of the formation of agrophytocenoses of oilseeds is the seedling survival before harvesting. The new hybrids Sumatra, Suzuka and Sumiko, compared with the Pioneer and Tristan hybrids, were also distinguished by high plant survival during the germination and harvesting period. Thus, on average for 2020-2022, the survival of Sumatra, Suzuka and Sumiko hybrid sunflower plants was in the range of 80.63-82.12%, or 2.34-3.35% more than the crop survival in the Pioneer (control) and Tristan hybrids.

Biometric studies to determine the height of plants have established the tallest plants on the crops of new hybrids Sumatra, Suzuka and Sumiko. According to the data obtained for an average of 3 years (2020-2022), the highest agrophytocenoses in the sunflower flowering phase at the level of 138.29-146.41 cm were determined in Sumatra, Suzuka and Sumiko hybrids. In the Pioner (control) and Tristan hybrids, the sowing height in the flowering phase was 134.41-134.82 cm, which is 11.59-12.00 cm less than in the new hybrids.

Table 4: Weather conditions during the sunflower growing season for 2020-2022 (data from the Kostanay weather station)

	Months			
Years	May	June	July	August
Mean monthly temperature, °C				
2020	17.20	17.8	23.30	19.80
2021	20.00	20.8	21.30	22.20
2022	13.70	18.6	21.60	20.10
Long-time average annual data for 10 years	13.70	20.0	20.90	18.90
Amount of rainfall, mm				
2020	80.60	23.1	17.40	69.50
2021	5.50	13.7	103.50	5.40
2022	53.40	21.1	81.20	15.00
Long-time average annual data for 10 years	36.00	35.0	56.00	35.00

Table 5: Comparative productivity of sunflower hybrids in the conditions of the Kostanay Region, the average for 2020-2022

Hybrid name	Yield, t/ha	Oil content, %	Oil yield, t/ha
Pioner (control)	1.15	48.35	0.56
Tristan	1.28	48.30	0.62
Sumatra	1.34	48.52	0.65
Suzuka	1.40	48.66	0.68
Sumiko	1.46	48.88	0.71
LSD_{05}*	0.05	0.180	0.03

*LSD_{05} is the least significant difference for a 5% significance level

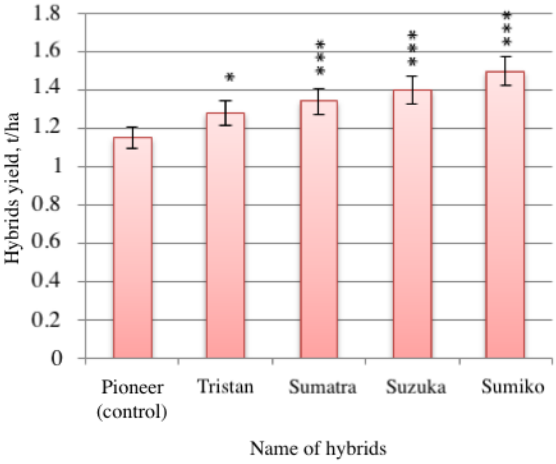

Fig. 1: Yield index of sunflower hybrids; (***$p<0.001$, **$p<0.01$, *$p<0.05$, ns $p\geq0.05$)

In the conducted study, special attention was paid to the yield and quality of oilseeds of selected hybrids.

As the research data showed, on average for 3 years (2020-2022) in the Pioner hybrid (control), the yield of sunflower oil seeds with an oil content of 48.35% was 1.15 t/ha and the oil yield was 0.56 t/ha, respectively. The highest productivity indicators were found in Sumatra, Suzuka and Sumiko hybrids. The yield of these new hybrids was 1.34-1.46 t/ha, or 0.19-0.31 t/ha or 16.52-26.96% more than in the control variant (Pioner hybrid) (Table 5).

In the studied new hybrids Sumatra, Suzuka and Sumiko, the oil content of seeds was also high and amounted to 48.52-48.88% or 0.17-0.53% more than in the control hybrid (Pioner). The new hybrids turned out to be in a better position for oil harvest, too. Thus, on average for 2020-2022, the Sumatra, Suzuka and Sumiko hybrids had an oil yield of 0.65-0.71 t/ha or 0.09-0.15 t/ha more than in the Pioner hybrid used by farmers.

The results of statistical analysis showed significant differences between the studied variants of sunflower hybrids in yield, oil harvesting and oil content of seeds at a significance level of 95%.

The comparative characteristics of the five sunflower hybrids (Fig. 1) showed different characteristics when cultivated in the chernozem soil of the Kostanay Region. The best yield indicators were shown by the hybrid Sumiko 1.46 t/ha (26% more compared to the control variant) ($p<0.001$). The Tristan, Sumatra and Suzuki hybrids also showed a result higher than the control variant by 11% ($p<0.05$), 16% ($p<0.001$) and 21% ($p<0.001$), respectively, compared to the control variant. The Pioner hybrid, which had been taken as a control variant, is resistant to many diseases, including broomrape infestation, gives consistently high yields in all weather and climatic conditions and has a high oil content. To date, the Tristan, Sumiko, Suzuka and Sumatra hybrids are actively used in cultivation in the conditions of ordinary chernozem in the arid climate of the Kostanay Region. The new hybrids showed greater responsiveness to soil and climatic conditions, which resulted in a significant increase in yield in all four experimental hybrids.

Study of the Effectiveness of Pre-Sowing Mineral Fertilizers for Sunflower Crops

According to the study goal in 2020-2022, four variants of mineral fertilizers used against the background of the main autumn application of $N_{40}P_{40}$ and different variants of pre-sowing fertilizers were studied in the conditions of the Kostanay Region.

According to the calculations data, the lowest field germination of sunflower (86.69%) and the lowest plant survival during the germination and harvesting period (76.77%) were observed in the control variant, i.e., when used the main mineral fertilizer $N_{40}P_{40}$ was used in autumn and $N_{10}P_{10}$ in spring when sowing.

The highest field germination of sunflower (88.41%) in experiment 2 was established on the variant with the $N_{40}P_{40}$ background in the autumn + $N_{30}P_{30}$ in spring when sowing. When we used $N_{20}P_{20}$ as a pre-sowing fertilizer, the field germination of sunflowers was at the level of 87.42% or a density of 43.71 thousand plants per 1 ha.

Against the background of the use of mineral fertilizers, along with the formation of a productive agrophytocenosis, it is important to preserve the seedlings obtained before harvesting. The highest survival of the plants that have germinated (43.43 thousand plants) before harvesting was established when an $N_{40}P_{40}$ background was applied in the autumn and $N_{20}P_{20}$ in spring during sowing, with additional foliar fertilizing of sunflower during the growing season with mineral fertilizers at a dose of $N_{10}P_{10}$ (80.51%).

According to the survival of sunflower plants in agrophytocenoses, variants 2 and 3 with doses of pre-sowing mineral fertilizers $N_{20}P_{20}$ and $N_{30}P_{30}$ occupied the intermediate position. In these variants, the survival of sunflower plants for the period of germination and harvesting was at the level of 78.38-79.86 or 1.61-3.09% more than in the control variant. In these crops, 34.26-35.30 thousand sunflower plants survived before harvesting in 1 ha of sowing.

Different variants of the use of mineral fertilizers had different effects on the height of sunflower crops. In the control variant, ($N_{40}P_{40}$ background in the autumn + $N_{10}P_{10}$ in spring when sowing) the height of sunflower plants in the flowering phase was 126.37 cm, while an increase in pre-sowing fertilizer to $N_{20}P_{20}$ contributed to an increase in the growth of sunflower plants to 135.61 cm with a difference of 9.24 cm. With a further increase in the dose of mineral nutrition to $N_{30}P_{30}$, the height of sunflower crops was 139.15 cm or 12.78 cm higher than the height of the control variant.

For the growth of sunflower plants, it was better to use $N_{40}P_{40}$ in the autumn + $N_{20}P_{20}$ in spring when sowing, as well as additional fertilizing during the growing season with mineral fertilizers at a dose of $N_{10}P_{10}$. In this combination, mineral nutrition contributed to an increase in the height of sunflower crops in the flowering phase to 145.28 cm and later in the filling and ripening phases to 148.70, 18.91 and 19.48 cm more than in the control variant.

To obtain a better and more productive yield, it is important to form normal indicators of the structure of the sunflower crop: The density of crops, the diameter of the calathid, the number of seeds in the calathid and the mass of 1,000 seeds. As the research data showed, in studies conducted in the conditions of the Kostanay Region, different doses of pre-sowing mineral fertilizers had different effects on the formation of structural elements of yield. At the same time, the highest indicators of the elements of the crop structure were formed in variant 4, where in the autumn period $N_{40}P_{40}$ was used and $N_{20}P_{20}$ was used in the spring, plus a top dressing was applied during the growing season of sunflower at a dose of N10P10. In this variant, the density of sunflower crops amounted to 35.21 thousand plants per 1 ha, exceeding the control variant by 1.93 thousand plants or 5.80% (Table 6, Fig. 1).

The average diameter of the sunflower calathid for an average of 3 years (2020-2022) was 15.90 cm, while other variants of using mineral fertilizers in the spring period during sowing contributed to an increase in the diameter of the sunflower calathid by 1.50-3.33 cm and with additional application of mineral fertilizers as a top dressing during the growing season of sunflower, the diameter of the calathid was 21.19 cm with a 5.29 cm bigger diameter of the sunflower calathid than in the control variant.

In the optimal use of mineral nutrition, the number of seeds in the calathid increased to 1,001 pieces with a mass of 1,000 seeds equaling 37.42 g. In the control variant, these indicators for sunflower plants were at the level of 909 seeds with a mass of 1,000 seeds equaling 33.51 g.

The variants using mineral fertilizers in doses of $N_{20}P_{20}$ and $N_{30}P_{30}$ when sowing sunflowers occupied an intermediate position in terms of the elements of the crop structure.

The results of statistical processing of sunflower crop structure data indicate significant differences in the use of mineral fertilizers at the level of 95%.

According to research data from 2020-2022, when using mineral fertilizers, the highest productivity of sunflower in terms of yield, oil collection and oil content was established on the variant of combined use of mineral fertilizers in autumn as the main fertilizer at a dose of $N_{40}P_{40}$, when sowing at a dose of $N_{20}P_{20}$ and during the growing season of sunflower as a top dressing at a dose of $N_{10}P_{10}$. In this variant, the yield of sunflower was 1.34 t/ha with an oil content of 48.60%, exceeding the control variant by 0.32 t/ha in yield and 0.24% in oil content according to these indicators. The harvest of sunflower oil on the best variant for the use of mineral fertilizers also amounted to 0.65 t/ha with an excess of the data of the control variant by 0.16 t/ha or 32.65% (Table 7).

Table 6: The effect of mineral fertilizers on the indicators of the elements of the structure of the sunflower crop, the average for 2020-2022

Variants of mineral fertilizer application	Density of crops, thousand plants/ha	Calathid diameter, cm	Number of seeds in the calathid, pcs	Weight of 1,000 seeds, g
$N_{40}P_{40}$ background in the autumn + $N_{10}P_{10}$ in spring when sowing (control)	33.28	15.90	909	33.51
$N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing	34.26	17.43	945	35.62
$N_{40}P_{40}$ background in the autumn + $N_{30}P_{30}$ in spring when sowing	35.30	19.23	974	36.89
$N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing + $N_{10}P_{10}$ as a top dressing	35.21	21.19	1,001	37.42
LSD_{05}*	0.05	0.06	4.7	0.02

*LSD_{05} is the least significant difference for a 5% significance level

Table 7: Indicators of productivity of sunflower oil seed quality depending on mineral fertilizers, the average for 2020-2022

Mineral fertilizer variants	Yield, t/ha	Oil content, %	Oil yield, t/ha
$N_{40}P_{40}$ background in the autumn + $N_{10}P_{10}$ in spring when sowing (control)	1.02	48.36	0.49
$N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing	1.17	48.44	0.57
$N_{40}P_{40}$ background in the autumn + $N_{30}P_{30}$ in spring when sowing	1.29	48.47	0.63
$N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing + $N_{10}P_{10}$ as a top dressing	1.34	48.60	0.65
LSD_{05}*	0.04	0.070	0.02

*LSD05 is the least significant difference for a 5% significance level

Against the background of the main application of mineral fertilizers $N_{40}P_{40}$, the variants using mineral fertilizers when sowing sunflower in rows at doses of $N_{20}P_{20}$ and $N_{30}P_{30}$ provided sunflower yields at the level of 1.17-1.29 t/ha, the oil yield of 0.57-0.63 t/ha with an oil content of 48.44-48.47%, thereby exceeding the productivity indicators of the control variant by 0.15-0.27 t/ha; 0.08-0.14 t/ha and 0.08-0.11%, respectively.

The results of the statistical analysis showed significant differences between the variants of mineral fertilizer use for sunflower crops in yield, oil collection and oil content of seeds at a significance level of 95%.

Study of Basic Tillage Techniques for Sunflower Cultivation

In conditions of the Kostanay Region, variants of basic tillage for sunflower crops were studied and the scientific data obtained showed different levels of biometrics indicators (height, density of crops) and productivity, quality (yield, oil content, oil yield) of sunflower depending on the method of basic tillage.

According to this experiment, the use of basic tillage on the no-till principle contributed to an increase in field germination and the survival of sunflower crops. Thus, on average for 3 years of the experiment (2020-2022), the field germination of sunflowers in the no-till variant was 89.07 with a density of crops at the time of germination of 44.53 thousand plants per 1 ha. In terms of field germination and the number of sunflower plants that have sprung up, the control variant using plowing as the main treatment is inferior to the no-tillage variant, by 0.84 thousand plants per 1 ha or by 1.68%, respectively.

The use of the no-till technique, along with field germination, improved the sunflower indicators for the survival of crops during the germination and harvesting period. Before harvesting, 35.51 thousand sunflower plants survived the agrophytocenosis in this variant compared to the control (plowing). Thus, crop survival equaled 79.74%. In the control variant using the method of basic plowing treatment, 34.33 thousand or 78.57% of 43.69 thousand ascended plants survived before harvesting, which is less by 1.18 thousand plants per 1 ha or the plant survival decreased by 1.17% compared to the no-till variant.

In the experiments, the most favorable conditions for the growth of sunflower plants were formed in the no-till variant. Thus, on average for 3 years (2020-2022) of the flowering phase, the highest agrophytocenoses of sunflowers with a height of 142.32 cm were formed in the no-till variant.

When plowing with a PLN 5-35 plow to a depth of 27-30 cm as the main tillage option, in the flowering phase, the height of sunflower plants was at the level of 135.67 cm and the difference in plant growth between the studied variants was 6.64 cm.

The key to the high productivity of crops is a better-formed crop with a sufficiently high density and optimal height. In conditions of the Kostanay Region, due to the better field germination, the survival of crops and higher plant height indicators, the no-till technique variant was in an advantageous position among the studied methods of basic tillage for sunflower.

On average, for 3 years of research on the no-till variant, the yield of sunflower was 1.16 t/ha or 0.15 c/ha or 12.93% more than in the control variant (Table 8).

The use of the no-till method contributed to improving the quality of sunflower seed oil. In this variant, on average for 3 years, the sunflower oil content was high and amounted to 48.49 or 0.13% higher compared to the control variant, where plowing with a PLN 5-35 plow to a depth of 27-30 cm was used as the main tillage (Fig. 2).

Due to the high yield and oil content, the studied no-till variant for sunflower crops provided a high oil yield. Thus, on average for 3 years (2020-2022), the oil yield during the use no-till technique was at the level of 0.63 t/ha, which is 0.07 t/ha or 12.5% more than in the variant with plowing.

As the results of statistical data processing have shown, the use of the no-till technique as the main tillage method, compared with the use of plowing with a PLN 5-35 plow to a depth of 27-30 cm increases the yield of oilseeds, oil content and sunflower oil yield at a significance level of 95%.

According to the results obtained, the yield, oil content and yield of sunflower oil with the no-till technique showed a higher result for all three indicators. Thus, the yield with the no-till technique increased by 0.15 t/ha ($p<0.001$). The level of oil content of seeds also turned out to be responsive to the no-till technique by 0.07% ($p<0.05$). At the same time, the oil yield from the seeds was 0.56 t/ha with the use of plowing and 0.63 t/ha with the no-till technique, which is 0.07 t/ha ($p<0.001$) higher. The absence of plowing may contribute to the accumulation and retention of more moisture, which may cause an increase in the studied indicators.

Table 8: Influence of basic tillage methods on the productivity indicators of sunflower oil seed quality, the average for 2020-2022

Basic tillage variants	Yield, t/ha	Oil content, %	Oil yield, t/ha
Plowing (control)	1.16	48.36	0.56
No-till	1.31	48.49	0.63
LSD_{05}*	0.02	0.060	0.01

*LSD_{05} is the least significant difference for a 5% significance level

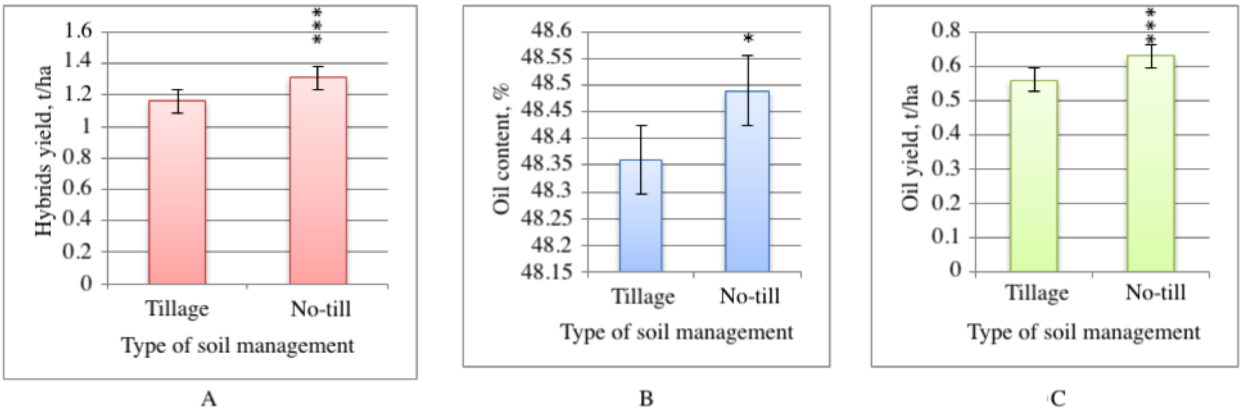

Fig. 2: Yield index (A), oil content of seeds (B), and yield of sunflower seed oil (C) depending on the method of basic tillage (***p<0.001, *p<0.05)

With the right choice of crop rotation, the no-till technique can contribute to better germination of sunflower seeds and access to nutrients. If all three parameters are considered when cultivating sunflower (the choice of a hybrid, fertilization and tillage), it can significantly increase the yield and oil content of the crop. The obtained results can be used for further optimization of sunflower cultivation parameters in various soil and climatic conditions.

Discussion

The studied new hybrids showed a high yield result (in the range of 1.34-1.46 t/ha) (Table 5). These data are consistent with the conclusions of (Ali *et al*., 2013), in whose studies the hybrids Hysun-33 and Hysun-38 were the most productive ones (Ali *et al*., 2013). In other studies, conducted in Pakistan, sunflower hybrids showed different reactions to plant height, stem diameter, calathid diameter, the mass of 1,000 seeds and seed yield. The SF-187 and Hysun-33 hybrids showed high productivity and were best adapted to the climatic conditions of Faisalabad (Sarwar *et al*., 2013).

Out study has shown that the new hybrids Sumatra, Suzuka and Sumiko with high field germination and survival of crops provided a high level of oil content at the level of 48.52-48.88% (Table 5). According to research conducted by Khokhar *et al*. (2006) at the Karadja Plant Breeding Research Institute, hybrids provide a high level of oil content and seem ideal for obtaining a high yield of grain and oil.

In our study, the new hybrids Sumatra, Suzuka and Sumiko differed with plant height in the range of 138.29-146.41 cm in the flowering phase, which confirms the conclusions of scientists that sunflower hybrids differ significantly in morphological characteristics and indicators related to yield (Ali *et al*., 2013; Sarwar *et al*., 2013).

As a rule, NPK levels significantly affect plant growth (Nasiyev *et al*., 2022b). In our study, a significant effect of NPK on plant height was obtained in the last variant with the use of $N_{40}P_{40}$ in the autumn + $N_{20}P_{20}$ in spring when sowing, as well as using a top dressing during the growing season in the form of mineral fertilizers at a dose of $N_{10}P_{10}$ (Table 6). In this combination of fertilizers, the height of the sunflower in the flowering phase was 145.28 cm and in the filling and ripening phase, it equaled 148.70 cm. Handayati and Sihombing (2019) came to the same conclusion that plant height increased significantly with increasing NPK levels.

The content of NPK significantly affected the diameter of the calathid. The largest increase in the diameter of the calathid to 21.19 cm was obtained at $N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing + $N_{10}P_{10}$ as a top dressing (Table 6). Another observation showed that this variant of using mineral fertilizers increased the number of seeds in the calathid to 1,001 and the weight of 1,000 sunflower seeds to 37.42 g (Table 6). The same result was also reported by Patil *et al*. (2009) in studies conducted at the agronomic farm of the agricultural college, Latur (India).

In studies conducted at the experimental garden of the Institute of Agricultural Technology Assessment of East Java (Indonesia), the best indicators of yield, calathid diameter, number of grains and weight of 1,000 grains were obtained when the crops were treated with full doses of NPK, where the highest grain yield was obtained (2.74 t/ha)

(Yuniza, 2018). In our study, the best variant for yield (1.34 t/ha) and oil harvesting (0.65 t/ha) turned out to be the one with the combined use of $N_{40}P_{40}$ in the autumn + $N_{20}P_{20}$ in spring when sowing, as well as a top dressing at a dose of $N_{10}P_{10}$ during the growing season (Table 7).

In the studies of the Zahak Agricultural Research Station conducted by Handayati and Sihombing (2019), the amount of N and P fertilizers had a significant impact on plant height, biological yield, seed yield and oil content in seeds. The largest amount of all measured factors was obtained with the treatment of 225 kg/ha of N and 150 kg/ha of P (Mollashahi *et al*., 2013). Our study, on the contrary, indicates the effectiveness of the use of mineral fertilizers according to the scheme $N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing + $N_{10}P_{10}$ top dressing. With this combination of NP fertilizers sunflower oil seeds with a maximum oil content of 48.60% were obtained (Table 7).

The no-till technique and retention of plant residues on the soil surface, the two components of conservation agriculture, have been identified as promising management methods for the sustainable intensification of agriculture for some time. Nevertheless, the introduction of the no-till technique by farmers in the arid Regions of Northern Kazakhstan has not yet occurred on a large scale, although the positive effect on yield has been repeatedly demonstrated by many scientists (Sessiz *et al*., 2008; Nasiyev *et al*., 2020).

As noted by Lipiec *et al.* (2006), the observed positive changes in soil quality were insignificant, but in combination with the economic efficiency offered by the no-till technique, this type of agricultural intensification provides an attractive option for farmers and can be recommended from the economical point of view, also considering the environmental efficiency.

In 2-year experiments (Pakistan) with various methods of tillage, tillage systems significantly affected the germination rate, crop survival, leaf area, vegetation duration, grain yield and the level of net profit (Wasaya et al., 2017). Similar data were obtained in our study. With the no-till technique, we received the largest number of seedlings per 1 ha of sowing (44.53 thousand plants) and high plant survival in agrophytocenoses during the germination and harvesting period (78.57%).

Based on the research conducted at the experimental farm of Bahauddin Zakaria University, Bahadur Laya Subcampus-Pakistan, (Sher *et al*., 2021) conclude that conservation tillage can increase sunflower yields in areas with low moisture availability and increase sunflower yields in areas with lower moisture capacity, conservation tillage could be proposed. In similar conditions of limited moisture in the north of Kazakhstan, we also obtained high sunflower productivity indicators (1.31 t/ha yield and 0.63 t/ha oil yield at an oil content of 48.49%) with the use of the no-till technique (Table 8).

Conservation tillage (the no-till technique) is any tillage practice in which crop residues remain in the fields before and after cultivation to reduce soil erosion and runoff losses (Galzki *et al*., 2011). Conservation tillage systems may have been more effective than traditional tillage systems and resulted in improved soil quality. In the current study, growth rates (plant height of 135.67 cm) were higher with the no-till technique compared to the tillage system using plowing included in the study. Conservation tillage saves soil moisture, since the soil is relatively dense, while less water and nutrients are washed out of the soil (Lopez *et al*., 2003; Paul *et al*., 2020), which contributes to better crop growth. Our results are consistent with several previous conclusions (Wang *et al*., 2017; Sher *et al*., 2018) regarding the growth and yield of sunflowers under various tillage systems.

Conclusion

1. Sumiko has the best yield potential of oilseeds compared to other hybrids, followed by the Suzuka and Sumatra hybrids. These hybrids are best suited for the arid conditions of Northern Kazakhstan
2. The NPK fertilizer affects plant growth and the yield of sunflower oil seeds. In general, the best plant growth and the highest yield were obtained with the combined use of mineral fertilizers according to the scheme $N_{40}P_{40}$ background in the autumn + $N_{20}P_{20}$ in spring when sowing + $N_{10}P_{10}$ as a top dressing. With this scheme of application of mineral fertilizers, the highest indicators of sunflower productivity were obtained. This scheme of application of NPK fertilizers can be recommended for growing sunflowers in the arid steppe of Northern Kazakhstan
3. The no-till technique creates the best conditions for the growth and development of sunflowers, positively affecting the level of yield, oil content and oil yield. The no-till technique can be recommended for Northern Kazakhstan with southern thin chernozem soils to increase the yield and oil content of sunflowers

Acknowledgment

The authors thank the reviewers for their contribution to the peer evaluation of this study.

Funding Information

The authors have not received any financial support or funding to report.

Author's Contributions

Both authors equally contributed to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

References

Ahmad, M. I., Ali, A., He, L., Latif, A., Abbas, A., Ahmad, J., ... & Mahmood, M. T. (2018). Nitrogen effects on sunflower growth: A review. *Int J Biosci*, *12*, 91-101. https://doi.org/10.12692/ijb/12.6.91-101

Ali, A., Aziz, M., Hassan, S. W., Asif, M., Ahmad, S., Mubeen, M., & Yasin, M. (2013). Growth and Yield Performance of Various Spring Planted Sunflower (*Helianthus annuus* L.) Hybrids under semi-arid conditions of Sargodha. Pakistan. *Science International (Lahore)*, *25*, 341-344.

Araus, J. L., & Cairns, J. E. (2014). Field high-throughput phenotyping: The new crop-breeding frontier. *Trends in Plant Science*, *19*(1), 52-61. https://doi.org/10.1016/j.tplants.2013.09.008

Dospekhov, B. A. (2018). *Methodology of field experience*. Al'yans. Moscow. ISBN-10: 9785903034963, pp: 33-64 (in Russian).

ElDala.kz. (2022). *Urozhay semyan podsolnechnika v Kazakhstane v 2022 godu uvelichen v dva raza* [Sunflower seed crop in Kazakhstan doubled in 2022]. https://eldala.kz/novosti/maslichnye/12631-urozhay-semyan-podsolnechnika-v-kazahstane-v-2023-godu-uvelichen-v-dva-raza (in Russian).

Fedin, M. A. (2017). *Methodology of state agricultural crop testing*. Agropromizdat, Moscow, pp: 25-30 (in Russian). https://gossortrf.ru/wp-content/uploads/2019/08/metodica_2.pdf

Galzki, J. C., Birr, A. S., & Mulla, D. J. (2011). Identifying critical agricultural areas with three-meter LiDAR elevation data for precision conservation. *Journal of Soil and Water Conservation*, *66*(6), 423-430. https://doi.org/10.2489/jswc.66.6.423

Ghani, A., Hussain, M., & Anwar, M. I. (2000). Effect of different levels of N fertilizer on yield and quality of sunflower (*Helianthus annuus* L.). *Int. J. Agric. Bio*, *4*, 400-401. https://www.fspublishers.org/Issue.php?y=2000&v_no=2&categoryID=10

Hammood, W. F. (2018). Effect of sorghum ratoon plants on accompanied weeds of crop. *International J. of and Nature*, *9*(1), 37-44.

Handayati, W., & Sihombing, D. (2019, July). Study of NPK fertilizer effect on sunflower growth and yield. In *AIP Conference Proceedings* (Vol. *2120*, No. 1, p. 030031). AIP Publishing LLC. https://doi.org/10.1063/1.5115635

Hussain, M., Waqas-Ul-Haq, M., Farooq, S., Jabran, K., & Farroq, M. (2016). The impact of seed priming and row spacing on the productivity of different cultivars of irrigated wheat under early season drought corrigendum. *Experimental Agriculture*, *52*(3), 491-491. https://doi.org/10.1017/S0014479716000314

Khokhar, M. I., Sadaqat, H. A., & Tahir, M. N. (2006). Association and effect of yield related traits on achene yield in sunflower. *Int. J. Agric. Biol*, *8*(4), 450-451. http://www. fspublishers.org

Lipiec, J., Kuś, J., Słowińska-Jurkiewicz, A., & Nosalewicz, A. (2006). Soil porosity and water infiltration as influenced by tillage methods. *Soil and Tillage Research*, *89*(2), 210-220. https://doi.org/10.1016/j.still.2005.07.012

Lopez, M. V., Moret, D., Gracia, R., & Arrue, J. L. (2003). Tillage effects on barley residue cover during fallow in semiarid Aragon. *Soil and Tillage Research*, *72*(1), 53-64. https://doi.org/10.1016/S0167-1987(03)00047-3

Martirosyan, A. V., Ilyushin, Y. V., & Afanaseva, O. V. (2022). Development of a distributed mathematical model and control system for reducing pollution risk in mineral water aquifer systems. *Water*, *14*(2), 151. https://doi.org/10.3390/w14020151

Mohammed, Y. A., Abdullah, B. H., Al-Kaisy, A. M. A., Abood, N. M., & Cheyed, S. H. (2019). Impact of Weeds to Sunflower under Zero Tillage and Phosphorus Fertilization. *The Iraqi Journal of Agricultural Science*, *50*(6), 1486-1494. https://doi.org/10.36103/ijas.v50i6.836

Mollashahi, M., Ganjali, H., & Fanaei, H. (2013). Effect of different levels of nitrogen and potassium on yield, yield components and oil content of sunflower. *Intl. J. Farm. & Alli. Sci*, *2*, 1237-1240. http://ijfas.com/wp-content/uploads/2013/12/1237-1240.pdf

Nardón, G. F., Botta, G. F., Aikins, K. A., Rivero, D., Bienvenido, F., & Antille, D. L. (2021). Seeding System Configuration Effects on Sunflower Seedling Emergence and Yield under No-Tillage. *Soil Systems*, *5*(4), 72. https://doi.org/10.3390/soilsystems5040072

Nasiyev, B., & Yessenguzhina, A. (2019). Adaptive sunflower cultivation technologies in West Kazakhstan. *Ecology, Environment and Conservation*, *25*(2), 672-676.

Nasiyev, B., Bushnev, A., Zhanatalapov, N., Bekkaliyev, A., Zhylkybay, A., Vassilina, T., ... & Tuktarov, R. (2022a). Initiation of safflower sowings in the organic farming system of Western Kazakhstan. *OCL*, *29*, 21. https://doi.org/10.1051/ocl/2022015

Nasiyev, B. N., Bekkaliyeva, A. K., Vassilina, T. K., Shibaikin, V. A. E., & Zhylkybay, A. M. (2022b). Biologized Technologies for Cultivation of Field Crops in the Organic Farming System of West Kazakhstan. *Journal of Ecological Engineering*, *23*(8). https://doi.org/10.12911/22998993/150625

Nasiyev, B., Bekkaliyev, A., Zhanatalapov, N., Shibaikin, V., & Yeleshev, R. (2020). Changes in the physicochemical parameters of chestnut soils in Western Kazakhstan under the influence of the grazing technologies. *Periodico Tche Quimica*, *17*(35), 192-202. https://doi.org/10.52571/PTQ.v17.n35.2020.18_NASIYEV_pgs_192_202.pdf

Osman, E. B. A., & Awed, M. M. (2010). Response of sunflower to phosphorus and nitrogen fertilization under different plant spacing at new valley *The Assiut University Bulletin for Environmental Researches*, *13*(1), 11-18. https://doi.org/10.21608/auber.2010.149260

Papatheohari, Y., Travlos, I. S., Papastylianou, P., Argyrokastritis, I. G., & Bilalis, D. J. (2016). Growth and yield of three sunflower hybrids cultivated for two years under Mediterranean conditions. *Emirates Journal of Food and Agriculture*, 136-142. https://doi.org/10.9755/ejfa.2015-05-291

Patil, V. D., Bavalgave, V. G., Waghmare, M. S., Kagne, S. V., & Kesare, B. J. (2009). Effect of fertilizer doses on yield and quality of sunflower hybrids. *International Journal of Agricultural Sciences*, *5*(1), 40-42. https://www.cabdirect.org/cabdirect/abstract/20093099106

Paul, P. L. C., Bell, R. W., Barrett-Lennard, E. G., & Kabir, E. (2020). Variation in the yield of sunflower (*Helianthus annuus* L.) due to differing tillage systems is associated with variation in solute potential of the soil solution in a salt-affected coastal Region of the Ganges Delta. *Soil and Tillage Research*, *197*, 104489. https://doi.org/10.1016/j.still.2019.104489

Sarwar, M. A., Khalil-Ur-Rehman, M. N., Javeed, H. M. R., Ahmad, W., Shehzad, M. A., Iqbal, S., & Abbas, H. T. (2013). Comparative performance of various sunflower hybrids for yield and its related attributes. https://repository.uaiasi.ro/xmlui/handle/20.500.12811/1835

Sessiz, A., Sogut, T., Alp, A., & Esgici, R. (2008). Tillage effects on sunflower (*Helianthus annuus*, L.) emergence, yield, quality and fuel consumption in double cropping system. *Journal of Central European Agriculture*, *9*(4), 697-709. https://hrcak.srce.hr/35462

Sher, A., Arfat, M. Y., Ul-Allah, S., Sattar, A., Ijaz, M., Manaf, A., ... & Gasparovic, K. (2021). Conservation tillage improves productivity of sunflower (*Helianthus annuus* L.) under reduced irrigation on sandy loam soil. *Plos One*, *16*(12), e0260673. https://doi.org/10.1371/journal.pone.0260673

Sher, A., Suleman, M., Qayyum, A., Sattar, A., Wasaya, A., Ijaz, M., & Nawaz, A. (2018). Ridge sowing of sunflower (*Helianthus annuus* L.) in a minimum till system improves the productivity, oil quality and profitability on a sandy loam soil under an arid climate. *Environmental Science and Pollution Research*, *25*, 11905-11912. https://doi.org/10.1007/s11356-018-1336-4

Sher, A., Suleman, M., Sattar, A., Qayyum, A., Ijaz, M., Allah, S. U., ... & Elshikh, M. S. (2022). Achene yield and oil quality of diverse sunflower (*Helianthus annuus* L.) hybrids are affected by different irrigation sources. *Journal of King Saud University-Science*, *34*(4), 102016. https://doi.org/10.1016/j.jksus.2022.102016

Wang, Z., Li, T., Wen, X., Liu, Y., Han, J., Liao, Y., & DeBruyn, J. M. (2017). Fungal communities in rhizosphere soil under conservation tillage shift in response to plant growth. *Frontiers in Microbiology*, *8*, 1301. https://doi.org/10.3389/fmicb.2017.01301

Wasaya, A., Tahir, M., Ali, H., Hussain, M., Yasir, T. A., Sher, A., & Ijaz, M. (2017). Influence of varying tillage systems and nitrogen application on crop allometry, chlorophyll contents, biomass production and net returns of maize (*Zea mays* L.). *Soil and Tillage Research*, *170*, 18-26. https://doi.org/10.1016/j.still.2017.02.006

Whish, J., & Bell, L. W. (2008, September). Trade-offs for ratooning sorghum after harvest to provide forage for grazing. In *Proceedings of the 14th Australian Agronomy Conference* (pp. 21-25). https://goo.gl/IpVDPq

Yuniza, S. (2018). The effect of pinching time and dose of npk fertilizer for the growth and yield of sunflower (*Helianthus annuus* L.) varieties sungold. *Jurnal Produksi Tanaman*, 6(5), 685-692. http://protan.studentjournal.ub.ac.id/index.php/protan/article/view/696

Zhao, X., Zhang, R., Chen, F., Maisupova, B., Kirillov, V., Mambetov, B., ... & Kelgenbayev, N. (2022). Reconstructed summertime (June-July) streamflow dating back to 1788 CE in the Kazakh Uplands as inferred from tree rings. *Journal of Hydrology: Regional Studies*, *40*, 101007. https://doi.org/10.1016/j.ejrh.2022.101007