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The influence of seeding time on growth development and productivity of sunflower in the dry steppe area

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ABSTRACT

Over the last five years, the drought-resistant crop of sunflower has been increasingly cultivated in the 1st dry-steppe zone of the Western Kazakhstan region. An important reserve for improving the yield rate of sunflower, along with the introduction of new highly productive varieties and hybrids, is mastering the agriculture methods. Especially important is the choice of the most optimal seeding time. In the adaptive technology of cultivating, seeding sunflower in the optimal time is one of the most important conditions that determine obtaining timely, vigorous and complete shoots, and good development of plants afterwards. The research was aimed at studying the elements of adaptive sunflower cultivating technology for providing high-quality raw materials to the manufacturers of vegetable oil. As a result of the research, data have been obtained about studying the elements of sunflower cultivation adaptive technologies, namely, the time of seeding in the conditions of the 1st dry-steppe zone of the Western Kazakhstan region, when sunflower is cultivated for seed and fodder.

Key words : *Sunflower, Seeding time, Photosynthetic potential, Growth, Plant development, Oilseeds, Silage, Yield*

Introduction

Diversification of the agriculture in the Republic of Kazakhstan has resulted in a significant shift towards the production of sunflower, which is largely due to the introduction of new varieties in hybrids, which allow increasing sunflower productivity.

The yield rate of sunflower is largely determined by the seeding time. Opinions of the researchers in this respect are rather contradictory. Many of them consider sunflower to be a crop of early seeding time, and recommend seeding it along with early cereals, basing on the fact that its seeds start germinating at the temperature of +4 to + 5 ^{o}C (Borisonik *et al.*, 1985; Pinchukov, 1990). However, at these temperatures the seeds germinate very slowly. In case of early seeding, high weediness is always observed, therefore, the yield of early sown plants significantly decreases.

In the conditions of the Western Kazakhstan area, this seeding time of sunflower has not been sufficiently studied. In the 1st dry steppe zone of the area, development of scientific bases and taking practical measures of improving adaptive technologies of cultivation are important for obtaining full-quality yields of sunflower, which is also crucial for improving the food safety and the fodder base. In this respect, the priority of the research was the studying of the sunflower seeding time, when sunflower is cultivated for seed and fodder, for satisfying the existing needs of the agricultural complex of the region.

Substantiation of the choice of the research area

With the aim of ensuring food safety of the Republic of Kazakhstan in the nearest future according to the Program of Agriculture Development in 2017-2021 as a whole, the work on diversification of plant cultivation through substitution of a part of the wheat acreage by more demanded crops (sunflower, barley, maize, fodder crops) will be continued (Program, 2017).

An important factor of improving efficiency of plant cultivation diversification in Western Kazakhstan and reducing the dependence of plant productivity on weather conditions is the expansion of seeding areas for the plants that are the most adapted to intermittent irrigation, such as sunflower, chickpeas, Sudan grass, sorghum and maize.

Diversification of agriculture abroad is considered to be one of the most important goals of greening the European agriculture policy. In Finland, diversification is considered as changing the structure of cultivated lands of farms by replacing the wheat monoculture with fodder crops, maize, sunflower, sorghum and their mixed sowing (Abd El-Lattief 2011; Nenko, 2016; Tagarakis, 2017).

In the recent years, in Western Kazakhstan, due to diversification of agriculture, manufacturers have started widely growing the drought-resistant crop of sunflower.

Sunflower seeds and their byproducts play an important role in the food complex of the country. The level of gross yield of seeds determines not only satisfying the needs of the population in food vegetable oil, but also significantly ensures supplying high-protein folder for livestock breeding. Obtaining products from sunflower is profitable due to the high added value.

In Europe, sunflower is proposed to be used along with other crops for diversification, which is probably due to its potential in adapting to the changes in the climate, competitiveness and attractiveness for production of food and energy (Makowski, 2000; Peltonen-Sainio, 2016; Smykal, 2015; Tagarakis, 2017).

Sunflower cultivation is important in the climatic conditions of Western Kazakhstan, which are characterized by heat and long vegetation period. In the recent years, sunflower acreage in the western Kazakhstan area has exceeded 40 thousand hectares, however the yield rate of oil seeds remains low (7.5-10.5 hw/ha). In this respect, development of adaptive technologies of sunflower cultivation is important for improving productivity and expanding the sunflower acreage.

The choice of optimal seeding time is important for obtaining high yields of sunflower in the system of adaptive technologies. The literature provides information about the possibility of cultivating sunflower without the introduction or use of herbicides before seeding and during sunflower vegetation through weed control due to intensification of agrotechnical methods (Penchukov, 1990; Pleskachev, 2001).

In the intensive technology of cultivating, seeding sunflower in the optimal time is one of the most important conditions that determine the obtaining of timely, vigorous and complete shoots, and good development of plants afterwards. Sunflower has been considered for a long time to be an early-sown crop. However, seeds of oil varieties in hybrids, when sown into cold soil, are affected by fungal diseases, weekly lose viability, which results in strong thinning and considerable yield reduction. In this respect, literature provides various data about seeding time (early, middle and late) (Sheveluha, 1986; Wolffhardt, 1987).

In Kazakhstan, elements of adaptive technologies of cultivating sunflower have been poorly studied. Besides, in the Western Kazakhstan area, virtually no research has been performed by other scientists with the use of sunflower.

As shown by the data in the summary, studying sunflower in various countries is focused on other quantitative characteristics of the soil, climate, level of plant productivity, and profitability of agricultural production. No similar researches have been made according to the proposed scheme in the conditions of the research area.

Methods

The research is performed at the experimental field of the West Kazakhstan Agrarian Technical University n.a. Zhangir Khan (Republic of Kazakhstan, Uralsk).

The soil at the experimental plot is dark-brown heavy-loamy limy-silty, the arable layer contains 51% of physical play. The arable layer of the soil contains 2.8 - 3.1% of humus. Accumulation of carbonates starts in the lower part of layer B, and reaches its maximum in layer C_K at the depth of 70 to 80 cm. The amount of absorbed alkali in the layer of 0 - 10 cm is 27.8–28.0 mg-eq per 100 g of soil. The layer above the depth of 80 cm is dominated by Cà; deeper layers are dominated by Ìg. The content of Na in the arable and subsoil layers is low - 3.1 to 3.6% of the total absorbed alkali. The one-and-a-half meter layer of soil contains (maximum water capacity) 672.5 mm of moisture, and holds (minimum water capacity) 481.3 mm, of which the productive moisture (active moisture range) is 236.7 mm; the arable layer is 160.8 mm; 102.1 mm; and 57.6 mm, respectively. Soil bulk density is measured from 1.22-1.28 g/cm^3 in the arable layer to 1.65-1.66 g/cm^3 at the depth of 80 to 120 cm.

By the morphological features of the genetic layers of the profile, and the agrochemical parameters of the arable layer, the soil of the experimental plot is characteristic of the dry steppe zone of Western Kazakhstan.

The area of the plots was 90 m^2, the experiment was repeated 3 times; the plots were placed at random. The Avant-garde hybrid was used for the experiments. The system of primary and secondary tillage was adopted for zone 1 of the Western Kazakhstan region.

In the research performed in 2018 during the first term, sunflower was sown on April 29 (after soil warming up at the depths of seeding up to 8-10°C) and in the second term - on May 9 (after soil warming up at the depths of seeding up to 12-14°C).

The density of sunflower plants in case of cultivation for oil seeds was 50 thousand plants per 1 ha, in case of cultivation for silage - 70 thousand plants per 1 ha. Currently, the most widespread and efficient method of showing sunflower is seeding with the interrow spacing equal to 70 cm.

In the research, the presowing tillage for sunflower in the first and the second terms of seeding included one presowing cultivation in the period of massive emergence of seedlings and germination of early weeds. In both cases, sunflower was sown on the day of presowing cultivation.

During the field experiments, accounting, observations of the onset of phonological faces and sunflower growth were performed according to generally adopted methods (Methods, 1972).

Photosynthetic activity of crops was studied according to the generally adopted methods.

The results of the research were statistically processed by the method of dispersion analysis with the use of computer software (Dospekhov, 1985).

Results and Discussion

Growth and development of sunflower depending on the seeding time

The choice of the optimal seeding time is an important factor for obtaining timely and vigorous shoots. The choice of the seeding time, along with the water holding capacity, is determined by the temperature of soil surface. Creating favorable conditions for plants' growth in the initial period, and the possibility of successful weed control in the presowing period depend on the correct choice of the seeding time and presowing tillage.

One of the main conditions for sunflower seeds' germination is creating conditions for absorbing water, which largely depends on the permeability of sunflower seeds' integument, and the water absorbing property of the seeds. In the period of germination, water absorption results in activation of numerous ferments' activity, which results in transformation of complex substances in the seed into simple substances, which are later used for forming the seedling.

Seeds of a modern varieties in hybrids contain relatively many protein compounds, which contain a lot of glutamic acid, proline and phenylalanine, which causes seeds' high enzyme activity during germination. Due to genetic peculiarities and changes in the chemical composition of sunflower seeds with high oil content, intensity of absorbing large amounts of water from the environment increases during germination. Sunflower seeds ability to absorb water also depends on the content of productive humidity in the soil, which in turn is determined by the seeding time.

According to the data of research in 2018, in case of seeding on April 29 (first term) sunflower germination was observed on May 13th, 14 days after sowing. Field germination rate for sunflower cultivated for oil was 92.60% (46.3 thousand plants per 1 ha), and for sunflower cultivated for silage, field germination rate was 94.64% (66.25 thousand plants per 1 ha).

In case of the second seeding date (May 9), field germination rate of sunflower was somewhat lower, compared to that of the first seeding date. Field germination rate for sunflower sown on May 9 cultivated for oil was 90.00% (45.0 thousand plants per 1 ha), and for sunflower cultivated for silage, field germination rate was 92.86% (65.0 thousand plants per 1 ha). In the variant with the second seeding date, full shots of the crop were noted on May 19, i.e. 10 days after seeding.

The results of observations show that, compared to the first seeding date, the period between seeding and shooting in the variant with the second seeding date decreased by 4 days. While for the seeding on April 29 (1st seeding time), duration of the period between seeding and shootings was 14 days, in the variant with the second seeding date (May 9), duration of this period was 10 days.

During the research, the main phases of sunflower development were also observed.

It is known that crops' development is largely dependent on important environmental factors like temperature, moisture content in the soil, feeding area, availability of soil nutrients, and photosynthetic active radiation. Under the action of the environmental factors, not only the duration of the interphase period changes, but certain shift of the entire cycle of sunflower organogenesis is possible.

In the zone of dry steppes of Western Kazakhstan, intensity of development and duration of the interphase periods of sunflower plants are largely dependent on the temperature and the moisture content in the soil. It is known that increasing temperature reduces the duration of only the first and the last stages of sunflower vegetation: appearance of shoots may be delayed in case of insufficient soil humidity and temperature, and the onset of full ripeness is accelerated in case of reduced water content in the soil, and decreased relative air humidity.

From the appearance of shoot until the formation of the calathide, sunflower is more demanding to care, therefore it is necessary to create for the plants the conditions that ensure their vigorous growth, promote formation of a larger number of flower rudiments in the calathide and formation of high yield. Sunflower development rate is especially determined by moisture content and temperature.

In the research performed in 2018, temperature changes in the absence of rain were noted in the period between the appearance of shoots and formation of the calathide. From phase of 2 real leaves to the phase of 7-8 leaves, sunflower developed in the conditions of decreased temperature (15-18^{0}C). After the phase of 7-8 real leaves, hot (35-38^{0}C) weather settled without rains. This factor accelerated the onset of the phase of calathide formation, especially in the sunflower sown on the second seeding date (May 9).

The results of the research showed that the phase of calathide formation in case of the first seeding date (before May 5) was noted on June 24. The duration of the period between shooting and calathide formation was 42 days.

In case of the second seeding day (before May 10), the onset of the calathide formation phase was noted on June 28th. The duration of the period between shooting and calathide formation was 40 days. In case of the second seeding date, the reduction in the period between shooting and calathide formation was 2 days, which was due to increased temperature during this period.

Intensive growth of the above-ground and underground sunflower organs was observed in the period between the calathide formation and flowering. This period for the sunflower plants sown on the first seeding date (April 29) lasted 14 days.

The duration of the period between calathide formation and flowering in the sunflower plants sown on the second seeding date (May 9) was 17 days.

By the end of flowering, stem growth terminated; however, in that period, the roots continued growing, and reached deeper layers of the soil. During that period, the leaves of the middle tier continued growing intensely.

The dynamics of sunflower linear growth depending on the seeding date

During sunflower calculation, formation of full-scale biometric data of the crops is important for obtaining sustainable yields. With that, uniformity of plants' height is one of the most important indicators that determine sunflower processability. Height uniformity determines the success of high-quality cultivation, and especially harvesting, which significantly reduces the process losses of the seed yield.

In terms of morphology, sunflower has a powerful green leafy herbaceous stem that is lignified in the bottom part and ends with an inflorescence. The surface of the stem is rough, dull, and has plurilocular hairs of two types: large conical hairs with thickened shells and sharp ends, and smaller curved moniliform hairs that consist of small roundish cells with thin walls.

The research has shown that before flowering, the calathide stimulates growth of the stem, and to some extent inhibits the growth of the plates of upper leaves. Between shooting and the appearance of

2-3 pairs of leaves, some flower plants grow slowly, and may be easily oppressed by weeds. During the research, no significant height deviations were noticed in all variants of the experiment before the budding phase. During the flowering phase, plant height formed almost completely.

Analysis of the dynamics of sunflower height gain during the vegetation period has shown that at the beginning of vegetation, in the phase of 2 pairs of real leaves, the plants sown on the first and the second seeding dates had the height of about 8.34 - 8.62 cm. Some height increase in the plants sown on the first and the second seeding dates was noted when the plants were cultivated for seeds with the density of 50 thousand plants per 1 ha. With increasing the crops' density to 70 thousand plants per 1 ha for obtaining silage, insignificant decrease in plants height was noted for the plants sown on both the first and the second seeding dates. By the phase of 7 to 8 pairs of leaves, linear growth of sunflower reached 23.10-26.50 cm in the variant with plants sown on the first seeding date, and 21.15-23.14 cm in the variant with plants sown on the second seeding date.

Further, within the period from calathide formation until the phase of full flowering, the increase in the linear growth was the greatest, and reached 50%. In the phase of calathide formation, the height of sunflower plants, depending on the seeding date and the agricultural purpose (seeds or silage), was 54.02 - 59.25 cm.

The measurement data show that the sunflower plants sown on the first seeding date, starting from the phase of 7 to 8 pairs of leaves, differed in height from the plant sown on the second seeding date. Sunflower plants cultivated for silage were inferior in their height to the plants cultivated for seeds, due to higher density of crops.

By the flowering phase, the height of sunflower plants sown on the first seeding day (April 29) had the height of 104 cm (silage) and 110 cm (seeds).

It is well known that the most active growing processes in sunflower occur in the period between the calathide formation and the flowering phases. In the conditions of 2018, not too favorable weather conditions were observed in the period between calathide formation and flowering (hot weather - 35-40^{0}C, with no rains), which, in turn, affected the growth processes in sunflower plants.

Growth intensity in this period is not only related to the hydrothermal conditions; this process is also related to the development of the root system. Within this period, nutrients and water are actively absorbed. Later, from the phase of seeds' formation until the phase of full ripeness, nitrogen, phosphorus and other elements are mainly supplied to the formed seeds through their mobilization from vegetative organs.

Indicators of sunflower photosynthetic activity

The leaf area and the dynamics of their surface formation are main indicators of sunflower plants' photosynthetic activity.

Intensity of light energy absorption by the leaves for photosynthesis depends on the optical density of seeding, which, in turn, is determined by the formation of sufficient leaf area of the crops.

Due to the fact that the leaf area value in the period of its maximum value is temporary, and therefore cannot be the only necessary, the dynamics of leaf surface formation is very important for assessing the photosynthetic activity of the plants, in addition to the maximum value of the leaf area.

In determining the photosynthetic potential, it is necessary to consider peculiarities of sunflower plants. Sunflower leaves are simple, petiolate, and do not have stipula. They are spirally arranged on the stem, and only the lowest 2-3 pairs of leaves are located opposite to each other. The number of leaves is mainly determined by the hereditary characteristics of plants, and is closely related to the duration of vegetation inherent to the genotype. The length and the width of leaves, depending on their tier and the environmental conditions, may vary significantly. For sunflower, the positive aspect is rapid defoliation during the phase of seeds' technological ripeness.

In addition to leaf surface, stems and calathides also participate in the formation of the photosynthetic potential of sunflower plants. With a significant number of leaves falling off, stems and calathides can ensure normal flow of the seed ripening process.

As shown by the dynamics of leaf surface formation in sunflower plants in 2018, at the beginning of vegetation it increases very slowly; within the first month after shooting, only 4-5% of the maximum leaf surface are formed. This process is accelerated later, and by the phase of calathide formation, sunflower leaves' area reaches 40-45% of the maximum. The largest leaf area was noted in the phase of full flowering, after which it gradually reduced due to leaves withering away at the bottom part of the stem.

In the research, sunflower leaf area depended on both the seeding time, and on the purpose of cultivating the plants.

In the phase of 2 real leaves, sunflower leaf area, depending on the variant of the experiment, varied between 0.50 and 0.78 thousand m^2/ha.

By the phase of 7-8 leaves, sunflower leaf area was about 2.55-4.05 thousand m^2/ha. With that, the largest leaf area was formed on sunflower crops sown on the first seeding date, and intended for silage.

In cultivation for seeds, the least leaf area was observed in the plants sown on the second seeding date – 2.55 thousand m^2/ha.

In the phase of calathide formation, sunflower leaf area increased to 5.92-9.64 thousand m^2/ha.

The weather conditions in the year of the research affected the rate of sunflower leaf surface development.

Leaves' unfolding ends in the phase of calathide formation, while their active growth that starts upon the appearance of 16 or 18 leaves, continues through the subsequent phases as well, and reaches the largest value (in case of favorable conditions for vegetation) in the period of flowering and at the beginning of seed ripening. The largest leaves are, as a rule, located between the 4th and 10th pairs. Starting from the period of calathide formation and until ripening, they make from 2/3 to 4/5 of the plants' leaf area. From the beginning of flowering, leaves of the top fourth of the stem start playing a significant role.

Cotyledons usually stay for 18-20 days, and die off upon the appearance of 4-6 pairs of leaves. The first pair of leaves in arid conditions increases in size within 8 to 12 days, and most often dries up by the beginning of calathide formation. However, such dying off is mainly due to the deficiency of moisture. In favorable conditions, the plant may keep all leaves until the phase of full ripeness. The second and the third pairs of leaves keep growing until calathide formation, and in case of water deficiency die off in the period between calathide formation and flowering. The 4th and 5th pairs of leaves start unfolding 10 - 15 days before calathide formation, and keep growing until flowering, usually remaining on the plant until full rightness. The leaves of the 6th through the 10th pairs unfold not long before calathide formation, keep growing until the beginning of ripening, and remain on the plant until full ripening for 60 to 70 days. Each pair of leaves from the 4th to the 10th pair makes about 1/10th of the total leaf area of the plant. Subsequent pairs of leaves (11 to 15, etc.) appear at the beginning of calathide formation, and keep growing until the end of seed ripening (Morozov 1978; Germogenov 2004).

Analysis of the research data shows that sunflower leaf area increases until the flowering phase. In the phase of flowering of the plants sown on the first seeding day (April 29), leaf area of the plants cultivated for seed was 12.01 thousand m^2/ha. With increasing the seeding density for obtaining silage, leave area increased to 14.93 thousand m^2/ha.

In the overall conditions of 2018, the unfavorable weather conditions (high temperature 35-40^{0}C without rainfall) during the periods of calathide formation, flowering, and ripening affected formation of sunflower leaf surface.

Sunflower productivity depending on sowing time

One of the reserves that allow increasing sunflower yields in the conditions of intensive agriculture is the wide introduction of hybrids adapted to the local conditions.

Studies on the influence of the seeding time on the productivity of the studied sunflower hybrid Avant-garde have shown that this hybrid virtually well reacted to the time of seeding.

Formation of sunflower plants productivity elements largely depends on the biological features of hybrids. High-oil hybrids are more productive when sown into well warmed-up soil, when soil temperature at the depth of seeding is not less than +8 to +10°C, i.e. on the first sowing date.

As shown by the data of the yield determination, high productivity of sunflower in the experiments was established when it was sown on the first seeding day, i.e. April 29. While the biological yield rate of the sunflower sown on the first seeding day was about 17.15 hw/ha, the biological yield rate of the sunflower sown the second seeding day (May 9) was 13.41 hw/ha.

The time of seeding also had influence on collection of green and dry mass in case of using sunflower for fodder, i.e. for production of silage.

In the conditions of 2018, the yield of silage mess collected in the phase of flowering was 162.14 hw/ha, and the yield of dry mass - 33.24 hw/ha (for the first seeding date). During the research, prolonging the seeding date until May 9 (the second seeding date) reduced the productivity of sunflower silage mass, compared to the first seeding date, by 13.69 hw/ha. With that, the yield of green and dry mass of sunflower was 148.45 and 32.48 hw/ha, respectively.

On the second harvesting date, sunflower silage mass productivity, depending on the date of seeding, was 159.14 hw/ha (second seeding date) and 179.97 hw/ha (the first seeding date), and dry mass - 37.53 hw/ha and 40.13 hw/ha, respectively.

Conclusion

Thus, for obtaining full-fledged harvest in the conditions of the dry steppe zone of the Western Kazakhstan region, sunflower should be sown on earlier dates - when the soil warms up at the depth of seeding to 8-10°C. Early seeding dates have positive effect on sunflower growth and development, and increase the yield of oil seeds and green silage mass.

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