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LUCERNE (*MEDICAGO SATIVA* L.) CULTIVATION AS COVER CROP UNDER RAINFED REGIONS IN SOUTHERN KAZAKHSTAN

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SUMMARY

With minimal soil tillage in mid-March, disking fields with LDG-10 harrow to a depth of 8–12 cm effectively destroyed emerging weeds and loosened the soil surface. In the favorable crop season of 2024, the highest dry hay yield (3.74 t/ha) obtained was under minimal tillage with simultaneous sowing of the early-maturing lucerne (*Medicago sativa* L.) cultivar Krasnovodopadskaya and safflower cultivar Irkas, exceeding pure lucerne by 1.68 t/ha (with a 1.8-fold increase). Compaction of lucerne with Sudan grass produced 2.84 t/ha (1.4 times higher than pure lucerne). In the extremely dry crop season of 2025, minimal soil cultivation in integration with sowing lucerne alongside the safflower cultivar Irkas resulted in a dry hay yield of 2.09 t/ha. A comparable hay yield of 2.04 t/ha resulted in the sowing of early-maturing lucerne cultivar Krasnovodopadskaya in combination with the Sudan grass cultivar Ailana-2017, which obtained a hay yield 2.2 times higher than the yield of pure lucerne. Under minimal soil cultivation with a single-species lucerne sowing, dry hay yield reached only 0.93 t/ha, remaining substantially lower than in the compacted cropping systems.

Keywords: Lucerne (*M. sativa* L.), safflower, Sudan grass, minimal soil tillage, mineral fertilizers, insecticides, herbicides, dry hay yield

Key findings: Under rainfed conditions, minimal soil tillage with direct sowing of lucerne (*M. sativa* L.) with simultaneous intercropping with safflower and Sudan grass significantly enhanced lucerne yield and produced a balanced fodder for livestock.

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INTRODUCTION

Perennial fodder grasses are an important source of nutritious fodder and also considerably contribute to soil protection and improvement. In the steppe zone of Northern Kazakhstan, lucerne (*Medicago sativa* L.), sainfoin, and fescue were mainly valuable economically due to highest productivity and resistance to stresses, providing hay and seed yields of 2.17 to 3.88 t/ha and 0.075 to 0.358 t/ha, respectively (Sagalbekov *et al*., 2022). Mixed cropping systems improve resource use efficiency and stability under variable environmental conditions (Xu *et al*., 2008; Mao *et al*., 2012; Prieto *et al.*, 2012; Hortal *et al.*, 2013).

Lucerne cultivation technology has reached sufficient exploration by numerous studies; however, the fodder shortage persists under arid conditions, largely due to violations in perennial grass cultivation practices. Therefore, development of resource-saving technologies, including minimum tillage and intercropping, is of great importance (Sydyk *et al*., 2012). Lucerne has gained wide cultivation worldwide and plays an important role in forage production. Its production and market value receive strong influences from environmental conditions and demand fluctuations, particularly under variable weather conditions (Hermias *et al*., 2024; Meirman and Masonichich-Shatunova, 2012). Legumes, particularly lucerne, play an influential role in improving soil fertility through biological-nitrogen fixation (Lupashku, 1988). Among the legumes, lucerne holds a leading position in stabilizing and restoring soil fertility and a significant stance in recommended crop rotations (Sydyk *et al*., 2012; Absatova *et al.*, 2019).

Recent studies revealed that due to economic and organizational constraints, using lucerne often took 4–5 years, resulting in a marked decline in productivity. Therefore, field experiments aimed at increasing seed productivity of old stands proceeded under rainfed conditions in the Turkestan Region (Sydyk *et al.*, 2020; Abdrasilov *et al*., 2020). The choice of cover crops and sowing technology should be dependent on the soil and climatic conditions, moisture availability, and the existing crop condition (Gubaidullin and Enikeev, 1982; Khramtseva *et al*., 2014). The effectiveness of intercropping lucerne with annual crops has attained studies widely showing both initial growth limitation and improved overall system productivity (Bengouga *et al.,* 2026; Chekalin *et al*., 2012; Sydyk *et al*., 2014a). A recommendation to grow lucerne with various cover crops arose to reduce weed pressure and compensate for low yields in the first year.

Lucerne has become one of the leading forage crops due to its highest yield, enormous nutritional values, and longevity (Chelobanova, 2003). The economic efficiency of perennial grass crops mainly depends on the productivity of semi-cover crops, while increasing the share of perennial grasses in crop rotations (25%–30%) and optimizing plant species composition further improve the sustainable productivity of forage lands (Lazarev and Pyatinsky, 2016). Obtaining the maximum green biomass yield was successful with the continuous use of lucerne along under sown Sudan grass, which considerably exceeded the control variants (Sidyq *et al*., 2023). The application of phosphorus fertilizers altered the dynamics of soil nitrate nitrogen during the growing season (Masaliyev *et al*., 2023) and improved the phosphorus and nitrogen content of plant biomass (Masaliyev *et al*., 2024). The biochemical composition of lucerne dry hay displayed characteristics of the highest nitrogen and potassium contents, while phosphorus concentration was mainly reliant on fertilizer levels. Therefore, the following study aimed to develop the resource-saving technology, including lucerne cultivation individually and in combination with safflower and Sudan grass with minimum tillage practices.

MATERIALS AND METHODS

Experimental site and procedure

Scientific research on the development of resource-saving technology for lucerne (*M. sativa* L.) cultivation individually and in combination with safflower and Sudan grass commenced at the South-West Research Institute of Animal Husbandry and Plant Growing — LLP, Shymkent, Kazakhstan. The experimental site location consisted of rainfed lands in the District Karatau, Shymkent Region, Kazakhstan. The study involved regionalized cultivars of three different crops, viz., lucerne (cv. Krasnovodopadskaya early maturing), safflower (cv. Irkas), and Sudan grass (cv. Ailana 2017).

Field experiments with two factors in a split-plot design transpired with a single-tier systematic arrangement of treatments. The first factor included soil cultivation methods (traditional, minimum tillage, and direct sowing), while the second factor consisted of crop variants (pure lucerne, lucerne + safflower, and lucerne + Sudan grass). The experimental design included traditional technology, minimum tillage, and direct sowing, with four replications on a total area of 3.0 ha. Plot sizes for the studied crop variants (pure lucerne, lucerne + safflower, and lucerne + Sudan grass) were 8000 m² for first-order plots and 1600 m² for second-order plots. Each treatment incurred replacement four times, with the data collected from the central area of each subplot to avoid border effects.

Observations and statistical analysis

During the crop-growing period, the data recorded comprised the following parameters—determination of nutrient content, phenological observations of lucerne and cover crops' development (safflower and Sudan grass), plant density in pure and cover crops, and crop structure in pure and cover stands. Data analysis used the analysis of variance (ANOVA) appropriate for a split-plot design, following the methodology of Dospekhov (1985). The significance of differences between treatments entailed evaluation using the least significant difference (LSD) test at the 0.05 probability level.

RESULTS AND DISCUSSION

According to Lupashku (1988), lucerne (*M. sativa* L.) crop was well adapted to serozem soils with moderate humus content and neutral to slightly alkaline reaction, which further confirmed the suitability of the experimental site for lucerne cultivation under rainfed conditions.

The water-physical properties of serozems are an important factor influencing lucerne growth under rainfed conditions. Under traditional technology, soil bulk density was 1.35 g/cm³ in the 0–20 cm layer and enhanced to 1.37 g/cm³ at 20–40 cm depth. Under direct sowing with the lowest soil compaction, the bulk density reached 1.33 and 1.35 g/cm³ in the 0–20 and 20–40 cm layers, respectively. A report on similar reduction in soil compaction under reduced tillage system occurred in the bulk density, confirming the positive effect of direct sowing on soil physical properties (Xu *et al*., 2008).

The highest soil moisture reserve accumulated by early March (198–203 mm in the 0–100 cm layer) due to the autumn-winter precipitation (Table 1). Analysis of variance (ANOVA) showed that soil moisture gained significant effects from year ($F = 23.574$, $p < 0.001$) and soil depth ($F = 140.171$, $p < 0.001$), whereas no substantial effect of tillage treatment was evident ($p = 0.878$). No noteworthy interactions between factors appeared. Post-hoc LSD test confirmed significant differences between soil depths ($p < 0.05$).

Subsequent warming and lack of rainfall caused soil crust formation under traditional and minimum tillage, which suppressed growth in individual sowing. According to Prieto *et al*. (2012) and Hortal *et al*. (2013), soil surface disturbance and moisture loss increased the risk of crust formation under fluctuating temperature conditions and precipitation regimes. This may lead to lucerne growth suppression under traditional and minimum tillage in the concerned study.

Table 1. Moisture reserves in the soil under lucerne sowings in the rainfed areas of Southern Kazakhstan for 2024–2025.

Sample collection dates	Productive moisture reserves (mm)																	
	Traditional technology						Minimum soil treatment						Direct sowing					
	0–20 cm		0–50 cm		0–100 cm		0–20 cm		0–50 cm		0–100 cm		0–20 cm		0–50 cm		0–100 cm	
	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025
03/08	42	29	98	92	198	186	43	31	101	93	200	189	45	33	105	96	203	190
03/18	43	23	99	80	197	162	44	24	100	82	201	163	46	26	106	83	205	167
03/28	41	15	97	40	189	83	42	16	98	41	191	86	43	18	99	45	194	86
04/08	39	12	90	33	183	69	40	14	92	34	185	71	42	14	95	36	188	73
04/18	34	8	84	28	174	62	33	10	84	30	175	63	35	11	87	31	177	64
04/28	29	6	78	21	162	53	30	7	80	22	164	54	32	8	82	24	166	57
05/08	26	1.5	65	13	145	48	27	1.5	64	15	147	49	30	2	66	16	149	51
05/18	21	1.5	58	11	131	45	22	1.5	55	12	134	47	25	2	60	13	138	48
05/28	20	1	53	10	121	44	21	1	54	12	123	46	23	1.5	55	12	126	46
06/08	9	2	51	10	112	44	10	1	52	11	113	45	14	2	54	11	119	45
06/18	7	1	45	6	100	33	8	1	48	7	103	35	10	1	50	8	109	36
06/28	3	-	39	-	93	-	4	-	39	-	94	-	4	-	42	-	100	-

Owing to heavy rainfall in March (127.8 mm) and early April (41.9 mm) 2024, early spring sowing was late and carried out on April 08, 2024. With sowing, productive moisture reserves were high, amounting to 42 and 183 mm in the arable soil layers (0–20 cm and 0–100 cm, respectively). Under minimum tillage, lucerne emergence began on the 8th–9th days after sowing, whereas under direct sowing, more uniform emergence was noticeable on the 6th–7th days, with full emergence occurring on the 8th–10th days. During the emergence period, the study recorded 23.2 mm of precipitation, accompanied by an average daily air temperature (16.4 °C), which further ensured rapid and uniform seedling emergence without soil crust formation. Sydyk *et al.* (2012) reported that sowing times and soil moisture appeared to be critical factors for uniform lucerne emergence under rainfed conditions. The delayed sowing and favorable moisture regime in 2024 resulted in rapid and uniform seedling emergence, confirming these observations.

Seeding density varied depending on cultivation technology and was highest under direct sowing due to improved seed-soil contact and uniform seed placement. These results are consistent with previous studies reporting better emergence under reduced soil disturbance (Sydyk *et al*., 2014a, 2014b).

The formation of productive elements in compacted agrocenoses differed depending on cultivation technology and crop biology in 2024. The recorded greater lucerne plant height (56.0–57.9 cm) emerged under direct sowing, whereas the lowest values (38.0–44.2 cm) occurred under traditional technology (Table 2). The said difference may be ascribable to the soil crust formation during the second half of April, when recording only 2.7 mm of precipitation, which eventually inhibited early growth of lucerne seedlings on bare soil. In contrast, safflower plant height ranged from 58 to 60 cm across all treatments and showed no consistent dependence on the applied agrotechnologies. According to Gubaidullin and Enikeev (1982), in the first year, lucerne growth showed sensitivity to surface soil conditions and moisture availability. Similar effects resulted in the presented study, where soil crust formation under traditional technology considerably limited the early plant growth.

Table 2. Nature of the formation of productive indicators of lucerne depending on cultivation agrotechnologies with compacted cover agrophytocenosis in 2024–2025.

Method of treatment	Options with compacting agrocenoses	Names of crops and weeds	Number of plants		Height of plants (cm)		Accumulation of raw biomass (g/m²)		Accumulation of dry biomass (g/m²)	
			2024	2025	2024	2025	2024	2025	2024	2025
Traditional technology	lucerne - clean sowing	lucerne	108.1	104.5	38.0	33.5	370	129.8	125.4	44.0
		weeds	-	-	-	-	105	83.5	50.6	41.4
	lucerne + safflower	lucerne	104.3	97.8	44.2	38.3	365	125.8	126.6	44.3
		safflower	28	53.8	60	44.8	550	435.8	165.0	117.3
		weeds	-	-	-	-	105	80.4	53.6	40.4
	lucerne + Sudan grass	lucerne	91.0	97.3	45.0	36.3	350	113.8	112.0	40.1
		sudan grass	33	70.0	85	109.0	225	386.8	72.0	105.0
		weeds	-	-	-	-	225	80.2	72.0	40.0
Minimal technology	lucerne - clean sowing	lucerne	109	99.4	49.5	34.2	415	128.9	132.8	43.6
		weeds	-	-	-	-	290	110.4	92.8	49.6
	lucerne + safflower	lucerne	143.7	96.9	50.0	39.2	390	124.0	124.8	41.8
		safflower	29	54.6	58	45.1	535	430.1	171.2	117.3
		weeds	-	-	-	-	245	104.6	78.4	50.5
	lucerne + Sudan grass	lucerne	110.4	99.6	60	38.9	465	123.2	144.6	39.8
		sudan grass	32	72.4	108	110.4	245	410.3	76.8	113.4
		weeds	-	-	-	-	195	106.2	62.5	50.9
Direct sowing (no-till treatment)	lucerne - clean sowing	lucerne	121.1	110.2	56.0	34.2	41.9	125.4	134.0	42.5
		weeds	-	-	-	-	317	110.2	101.4	49.8
	lucerne + safflower	lucerne	198.2	101.3	57.0	37.8	342	127.2	109.4	43.4
		safflower	28	50.0	61	42.4	562	427.6	179.8	111.3
		weeds	-	-	-	-	222	105.4	71.0	60.0
	lucerne + Sudan grass	lucerne	152.0	104.6	57.9	39.2	495	126.4	158.4	42.5
		sudan grass	30.0	75.1	92	111.2	251	398.6	80.3	110.6
		weeds	-	-	-	-	210	106.4	67.2	60.2

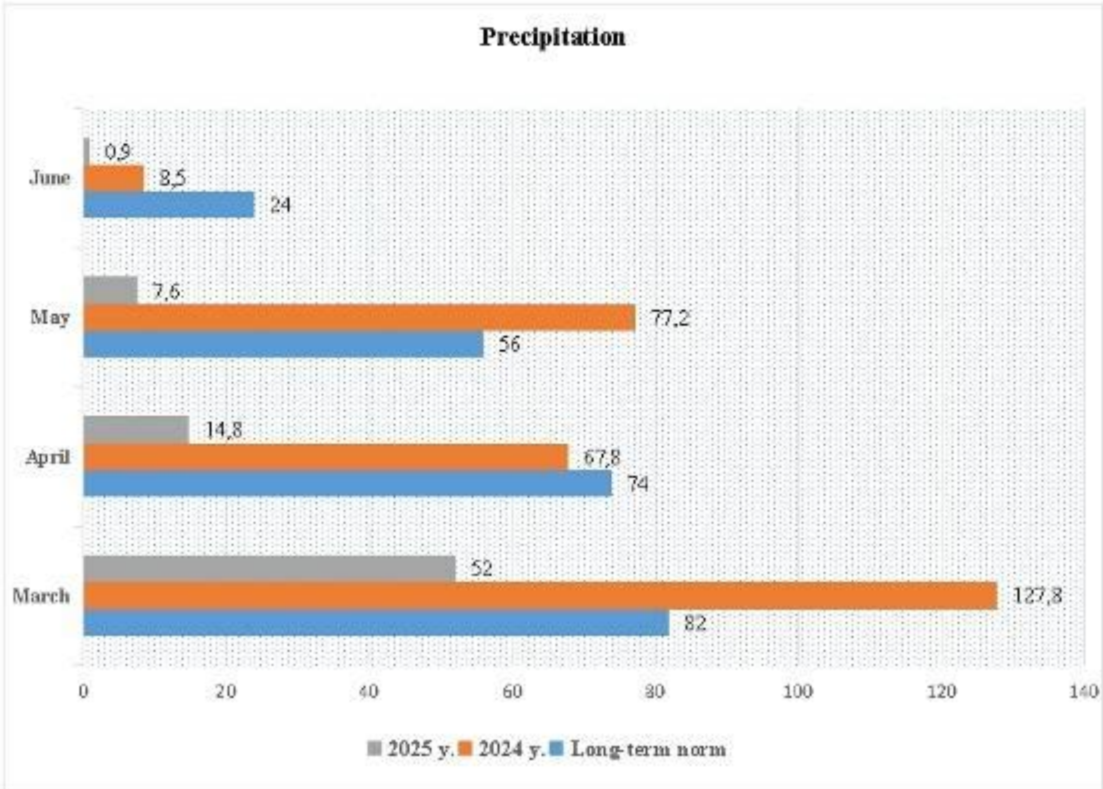

Figure 1. Precipitation during the lucerne growing season in the study area according to data from the Shymkent-Agro weather station (2024–2025).

During early May, precipitation amounted to 16.1 mm in the first ten-day period, 39.4 mm in the second, and 21.7 mm in the third (Figure 1). Predominantly intense rainfall favored the growth and development of lucerne and the cover crops (safflower and Sudan grass) under all cultivation methods. The Sudan grass with the highest plant height (108 cm) was notable under minimum tillage. This effect indicated associations with effective weed control, loosening and mulching of the upper soil horizons, and the retention of productive moisture in deeper soil layers.

The highest biomass accumulation was evident in lucerne intercropped with safflower under sowing, confirming the advantage of compacted agrocenoses reported in previous studies. The compaction of lucerne with annual fodder crops enhanced the biomass accumulation (Sydyk *et al*., 2014a, 2014b; Sagalbekov *et al.*, 2022). In this study, the higher raw and dry biomass obtained in compacted agrocenoses also got support from these past findings. Similar trends have come out from international studies, where intercropping systems improved biomass production through more efficient resource use (Mao *et al*., 2012). However, the highest biomass values observed in this study could be in connection with local soil and climatic conditions.

The lowest dry hay yield of individual lucerne sowing (1.75 t/ha) surfaced from traditional technology under the weather and climatic conditions of 2024. In contrast, the combined sowing of lucerne with safflower increased the dry hay yield to 2.28 t/ha, while the integration of lucerne with Sudan grass under traditional technology resulted in the higher yield (2.56 t/ha). Under minimum tillage, the combined sowing of lucerne and safflower cultivar Irkas revealed the highest dry hay yield (3.74 t/ha). Combined sowing of lucerne and Sudan grass resulted in dry hay

Table 3. Dry hay productivity of lucerne under different cultivation technologies and agrocenosis compaction with safflower and Sudan grass in 2024–2025.

Method of treatment	Options with agrocenosis compaction	Average yield (t/ha)	
		2024	2025
Traditional technology	lucerne - clean sowing	1.75	0.85
	lucerne + safflower	2.28	2.00
	lucerne + Sudan grass	2.56	1.85
Minimal technology	lucerne - clean sowing	2.06	0.93
	lucerne + safflower	3.74	2.09
	lucerne + Sudan grass	2.84	2.04
Direct sowing (no-till treatment)	lucerne - clean sowing	2.36	0.92
	lucerne + safflower	3.60	2.15
	lucerne + Sudan grass	3.06	2.13
Smallest significant difference$_{0.5}$		0.181	0.76

yield of 2.84 t/ha, which was 1.4 times higher than that of lucerne sowing alone (2.06 t/ha). From direct sowing, dry hay yield reached 2.36 t/ha (Table 3). Differences between treatments reached evaluation using the least significant difference (LSD) at $p \leq 0.05$. Chekalin *et al*. (2012) and Sydyk *et al*. (2014a, b) reported that compaction of lucerne with annual cover crops increased the dry matter yield by reducing weed pressure and improving resource use. These findings were greatly analogous to the results obtained in the presented study. Compared to international studies, where yield increases typically ranged from 20%–40%, the higher increase observed in this study (up to 1.8-fold) highlights the effectiveness of intercropping under arid conditions.

In 2025, extreme drought conditions with high temperatures and low precipitation significantly reduced lucerne growth and productivity. However, intercropping with safflower and Sudan grass mitigated yield losses due to their higher drought tolerance. Reports of similar effects have resulted in previous studies (Lupashku, 1988; Chelobanova, 2003). At the beginning of April, light rainfall (14.7 mm) combined with warm weather promoted the deeper root development of young lucerne seedlings and cover crops. Safflower density ranged from 28 to 33 plants/m², while for Sudan grass, the said range was 49–68 plants/m², depending on soil cultivation methods. The cover crops developed uniformly at the initial growth stage. In the second half of April, without precipitation, the average daily air temperature increased to 19.9 °C, while in April, the total rainfall (14.8 mm) was five times lower than the long-term average.

Throughout May, no recording of effective precipitation happened, with a total of only 7.6 mm. The average monthly air temperature reached 23.4 °C, while daytime temperature peaked at 39 °C–41 °C on May 14–16, 2025, exceeding the long-term average by 4.1 °C. These environmental conditions resulted in an extreme soil and atmospheric drought. Productive moisture reserves declined sharply, ranging from 1.5 to 3.0 mm in the 0–20 cm layer, 15–17 mm in the 0–50 cm layer, and 45–52 mm in the 0–100 cm soil horizon (Figure 2).

With the onset of June, average air temperature increased to 25.6 °C, exceeding the long-term average by 2.7 °C, while precipitation during the first ten-day period was negligible (0.9 mm). Under the extremely dry conditions of 2025, by the end of the second ten-day period, lucerne plant height from sowing alone ranged from 27 to 30 cm. In combination of lucerne and cover crop safflower, the lucerne plant height increased to 30–33 cm, and safflower reached 43–46 cm. By sowing lucerne with Sudan grass, lucerne plant height reached 32–34 cm, whereas Sudan grass attained the plant height of 104–105 cm. In 2025, the severe drought reduced the dry hay yield of pure lucerne (0.85 t/ha), whereas cover crops safflower and Sudan grass emerged with increased yields (20.2 and 1.85 t/ha, respectively). The higher productivity of

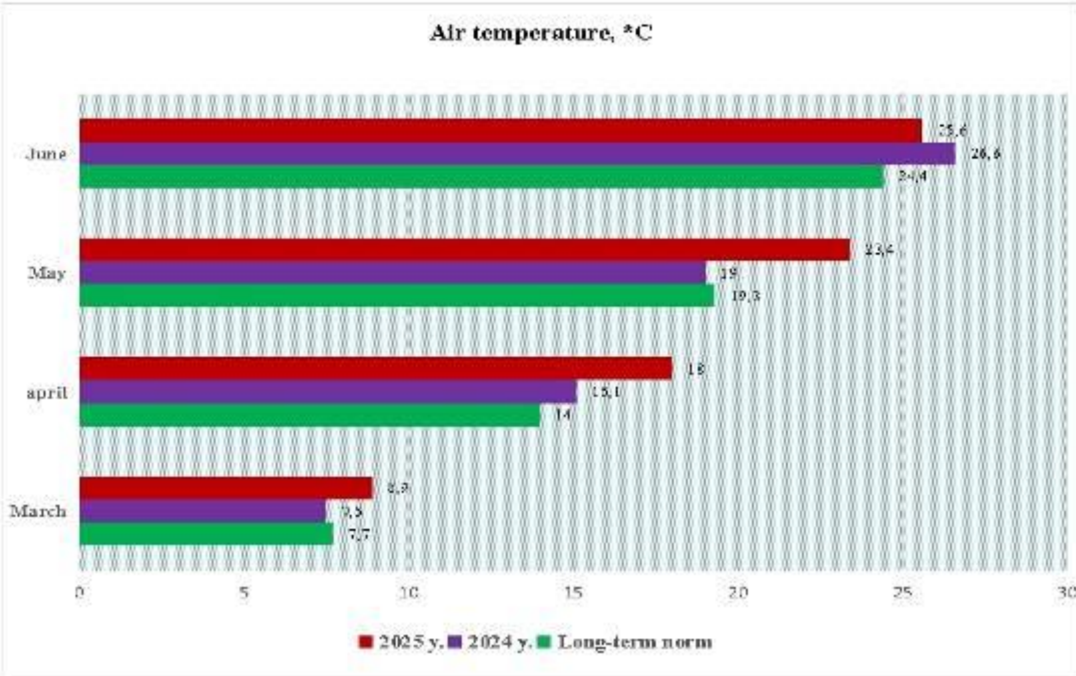

Figure 2. Air temperature during the lucerne growing season in the study area according to data from the Shymkent-Agro weather station (2024–2025).

compacted agrocenoses referred to the drought tolerance of cover crops, which mitigated stress on lucerne, with the same findings also reported in previous studies (Lupashku, 1988; Chelobanova, 2003).

In 2025, lucerne cultivation used direct sowing (no till) technology. With direct sowing, dry hay yield reached 0.92 t/ha, which was 0.07 t/ha higher than the traditional technology and 0.01 t/ha lower than the minimum tillage. The higher performance of direct sowing revealed an association with improved seed-soil contact and uniform seed placement at the depth of 1.0–1.5 cm, resulting in higher germination and more uniform crop stand in the field. However, under direct sowing, the weed infestation was higher than under traditional and minimum tillage systems. Increased competition with weeds likely stimulated faster growth of lucerne plants, contributing to improved agrophytocenosis productivity. Xu *et al.* (2008) and Mao *et al.* (2012) reported that the direct sowing system often increased early weed pressure but can stimulate crop competitiveness under limited soil disturbance. In this reported study, similar effects were evident on the lucerne growth traits with no-till conditions. However, in contrast to some international studies, the yield advantage observed in this study suggests improved crop competitiveness under local conditions. Direct sowing improved crop establishment but increased weed pressure, which may enhance crop competitiveness (Xu *et al.*, 2008; Mao *et al.,* 2012). Intercropping systems under these conditions supported the concept of complementary resource use (Prieto *et al*., 2012).

CONCLUSIONS

The highest dry hay yield (3.74 t/ha) obtained emerged from minimal soil treatment when sowing lucerne (*M. sativa* L.) cultivar Krasnovodopadskaya simultaneously with safflower cultivar Irkas, which exceeded the hay yield of sole lucerne sowing by 1.68 t/ha and showed a 1.8-fold increase. With direct sowing of lucerne with safflower, the dry hay yield at the budding stage reached 3.60 t/ha, which was 1.24 t/ha higher than the lucerne crop alone. A substantial increase in dry hay yield (3.06 t/ha) was also notable when planting lucerne together with Sudan grass using direct sowing, resulting in a 1.3-fold increase compared with sole lucerne sowing. In the extremely dry year of 2025, direct sowing of lucerne with safflower produced a dry hay yield of 2.15 t/ha at the budding stage, which was 1.23 t/ha higher than that of sole lucerne sowing. Sowing lucerne together with Sudan grass under direct sowing conditions in 2025 also ensured an acceptable yield increase of 2.13 t/ha. Overall, the compaction of agrocenoses with safflower and Sudan grass proved an effective practice for increasing dry hay yield under the hot and arid climatic conditions of Southern Kazakhstan.

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