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ALFALFA (*MEDICAGO SATIVA* L.) HAYMAKING TIMING EFFECTS ON ITS YIELD AND QUALITY IN KYZYLORDA REGION, KAZAKHSTAN

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SUMMARY

In the context of marketability, economic value, and agricultural effectiveness to meet the feed demand of animal husbandry, it is necessary to create a solid forage base in the Kyzylorda region, Kazakhstan. The thriving solution to increased livestock and animal husbandry productivity in ecological conditions of the Aral Sea region principally depends upon the timely procurement of feed and the establishment of industrial-based feed production. Producing enhanced high-quality feeds can be the outcome of introducing high-yielding varieties, using new resource-saving cultivation and harvesting technologies, organizing optimal cultivation and production processes, and increasing the efficiency of various technical means. Of all the harvested types of feeds, alfalfa (*Medicago sativa* L.) has the best effect on increasing the livestock's milk and meat yield. All farm animals can also consume the green mass of alfalfa much faster. In feeding cattle with alfalfa, its utilization rate is 92.6%. On biochemical composition, alfalfa hay surpasses various other feeds, and 100 kg of alfalfa hay contains 11.6 kg of digestible protein, 1.77 kg of calcium, 0.22 kg of phosphorus, and 4.5 g of carotene. In conditions with rice crop rotation and according to its biological characteristics, alfalfa is indispensable in agrotechnical and reclamation relations, especially in saline soils. The economic value of alfalfa lies in its broad ecological plasticity, high productivity, and ability to grow back quickly after mowing.

Key words: Alfalfa (*Medicago sativa* L.), timing of haymaking, animal husbandry, growth dynamics, fodder yield, biochemical composition, quality

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Key findings: Under the environmental conditions of the Kazakhstan Aral Sea region, for the preparation of a highly nutritious alfalfa haylage with a high digestibility, its mowing must be "from the beginning of budding to the beginning of flowering," in which the duration of mowing should not exceed 10 days with an optimal cut height of 4–6 cm.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the most valuable forage crops grown worldwide in more than 80 countries and an area of over 40 million ha (Bouton, 2007). In Kazakhstan, in 2022, the total alfalfa crop area was 2,149,774.3 ha, and the alfalfa hay total production was 437,455.5 t. In ecological conditions of the Kyzylorda region, Kazakhstan, alfalfa is an integral and essential plant in rice crop rotation, with an area of 67,318.6 ha and alfalfa hay production amounting to 25,038.3 t that continues to increase in the region (Akimat of Kyzylorda region, 2023).

Alfalfa hay ranks stable among the most valuable forage crops due to its green mass' high content of nutrients and minerals. Alfalfa uses include making a variety of byproducts, i.e., hay, herbal protein-vitamin flour, haylage, silage, and as an additional green feeding. Such diverse uses are due to its rich mineral and vegetable protein contents and essential amino acids.

Past studies have reported that in addition to provitamin A (carotene), alfalfa contains vitamin B_1, which prevents diseases of the nervous system and is vital in managing the carbohydrate metabolism in the animal body; vitamin C - antiscorbutic; vitamin D - antirachitic; vitamin K - affecting blood composition (blood clotting); vitamin PP - preventing pellagra in animals, and vitamin E - affecting the reproductive ability of the animals (Zykov, 1967; Bastaubayeva *et al*., 2023). The findings of Cui *et al.* (2018) revealed that intercropping can increase plants' biomass and reduce the accumulation of heavy metals in plants. However, in ryegrass and alfalfa crop intercropping, the lead content in the shoots and roots was significantly lower than in their monoculture.

The Kyzylorda region, Kazakhstan, located geographically in severe unfavorable environmental conditions, needs implementing crop production. A decreasing water resource exists at the transboundary Syrdarya River in Central Asia, creating specific threats to a secure water supply for irrigation, causing intense desertification, salinization, and soil blowing (Tokhetova *et al.,* 2022; Sabra *et al*., 2023). In the Kyzylorda region, the wet alfalfa hay yield for the second and subsequent years of life can reach 15.0–18.0 t/ha (Zykov, 1962; Razin, 1973; Gubaidullin and Enikeev, 1982). In irrigated conditions, establishing the number of haymaking is mainly by the duration of the frost-free period with an air temperature of at least 10 °C. Therefore, in the Kyzylorda region, where the frost-free period lasts 170–180 days, it is possible to have three or four haymaking cycles. Preparing high-quality hay, herbal protein-vitamin flour, and haylage requires alfalfa silage as an essential reserve in creating a forage base for livestock in the region. In this regard, proper and timely harvesting, drying, and storage of alfalfa can fulfill the feed demand of the livestock.

Harvesting alfalfa for hay has been well known to cause losses significantly of the plants' most nutritionally valuable parts, like leaves and flowers, since these parts dry out faster and shatter during mowing, stacking, and other harvesting operations. Therefore, the main challenge in harvesting alfalfa is to minimize the loss of leaves, buds, and flowers. In addition, physical and chemical changes also occur in the feed as it dries under field conditions. Primary biological and metabolic losses occur due to plant respiration (Rotz and Muck, 1994). Thus, the chief purpose of this research was to study the timing influence of haymaking on the yield and quality of alfalfa feed in the conditions of the Kazakhstan Aral Sea region.

MATERIALS AND METHODS

In obtaining high-quality hay, it is compulsory to harvest alfalfa in the best agrotechnical terms without a gap between mowing, pressing, loading, and transporting the hay. It is also essential to note the broad differences between the haymaking methods performed in wet and arid regions. In wet regions, hay growers speed up hay drying by improving hay bale ventilation using conservants, such as propionic acid, to keep the product for extended periods in humid conditions. However, in arid regions, pressing hay is often after the dew has accumulated on the soft tissues of the plants to reduce leaf loss. For the same reason, researchers have developed new systems for spraying water mist on plant tissues during pressing (Shinners *et al.,* 2006).

Haymaking and silaging are also well-known traditional methods of conservation of forage crops. However, yield loss and hay quality during different harvesting periods was 30%–70% of the potential alfalfa yield (Glover and Melton, 1996; Roman and Hensel, 2014; Orloff *et al.,* 1997). Until now, this issue has lacked attention in the conditions of the Aral Sea region. Therefore, more research needs to focus on this particular issue to minimize losses, especially the haymaking time according to the stages of alfalfa development. It is worth noting that the ultimate goal of the haymaking machinery is to maintain the highest possible nutritional value of the hay; therefore, it is important to understand the impact of harvesting methods on the quantity and quality of harvested hay.

Experimental conditions

The Kyzylorda region's climate is sharply continental. Its experimental field soil is meadow-boggy with a low humus content of up to 1% and a high value of the dissolved solids at 0.65%–0.88%. The salinity type is chloride-sulfate and medium saline (Tokhetova *et al.,* 2020).

Studies commenced in several farms of the region, according to the methods of conducting field experiments, to determine the alfalfa's weight gain and growth dynamics over time (Kepner *et al.,* 1978). For accurate experiments, performing the second haymaking period continued. Carrying out the studies on selected fields, with replications, contained 12 plots sized 1.0 m × 1.0 m marked with a tape measure and pegs. These studies ensued every five days after the first haymaking.

In the first plot, out of 12.5 days after the first haymaking, cutting off all alfalfa used a pruner at the root. Of these, selecting 100 measurements of the weight and growth of stems proceeded. At the same time, using medical scales of the VNZ-2000 GOST 574-75 type helped measure the weight, and a meter ruler measured the growth. The measurements showed that the alfalfa cutting height ranged from 3.8 to 8.0 cm. The average weight at this growth turned out to be 0.9 g. The measurement errors were for weight gain (±0.2 g) and height gain (±1.0 mm).

Similarly, every five days, 100 measurements of the weight and height of the stem growth occurred in all plots. If, in the first plot, they cut with pruners and measured the weight and height five days after haymaking, the second plot had a similar operation performed 10 days after haymaking, and the third plot, it was 15 days after haymaking, adding five more days at succeeding plots until the end. Table 1 shows the average measurements to determine the alfalfa stem's weight gain and growth dynamics over time. In the study of the seventh plot, the stem's growth reached 52–76 cm, with the average weight being 8.5 g, and buds appeared in alfalfa. On the 40th day after haymaking, the mean stem weight reached 10.9 g, while the alfalfa began to bloom, and in probing the ninth plot, the alfalfa weight attained 12.3 g. As it turned out, after measuring the 10th plot, the average stem weight was 11.8 g as the maximum.

Table 1. Average weight gain and growth dynamics of alfalfa over time.

Plot number	Number of days after haymaking (#)	Average height of stem (cm)	Average weight of stem (g)
1	5	5.53	0.9
2	10	7.8	1.3
3	15	11.4	1.85
4	20	19.72	2.6
5	25	38.0	3.7
6	30	58.4	5.4
7	35	67.0	8.5
8	40	75.2	10.9
9	45	84.3	12.3
10	50	84.9	11.8

Field experiments can provide an unbiased assessment of the options under study only if experimentation is to fulfill all the requirements of the techniques. Technical errors made at any stage of the experimentation violate the comparability of options and distort their effectiveness. Errors of this kind are difficult to correct by any mathematical processing and, hence, completely invalidating the experimental results. Therefore, for experimenting in the field, observing all technological rules is imperative for obtaining accurate results suitable for an objective research assessment.

Thus, studies from several years have shown that irrigation conditions of the Kyzylorda region and timely harvesting of alfalfa for hay can provide three to five haymaking cycles (Zykov, 1962, 1967; Razin, 1973). By carrying out haymaking in the early vegetative stages, the subsequent regrowth occurs mainly from the axillary buds of the stem remaining after mowing and by harvesting during the flowering period - from dormant and additional buds of the head (crown) of the root. Therefore, the best time for harvesting alfalfa for hay is from the flowering's start to full flowering, which covers 11–12 days. The data of the studies became fundamental factors for optimizing the timing and number of alfalfa haymaking. However, it is worth noting that forming the first haymaking requires 55–60 days, with the second haymaking at 25–30 days and the third at 40–45 days.

Haymaking of alfalfa during the budding and flowering's start has justifications that at this age, the alfalfa produces better quality hay. Although, it is relatively inferior in yield compared with haymaking carried out during the full flowering period. However, due to higher nutrient contents, the yield shortage gains compensation from the total nutrients per unit area, especially the proteins (Nurymov, 1995; Nurymov *et al*., 1992). Performing haymaking at the end of budding and the beginning of flowering is also valid because alfalfa produces more yield at this time (Myrzabek, 1998; Alimbetov, 1991).

Thus, according to Zykov (1967), mowing the forage alfalfa is best with the following periods, i.e., flower buttons probing (by 60%–70%), mass budding (60%–70%), the appearance of flowers (20%–30%), mass flowering (60%–70%) of the main stems, and the beginning of seed formation. The accounting of the yield of green mass and hay during the harvesting of alfalfa in varied vegetative phases has shown that the systematic mowing of alfalfa at the age of buttons probing and budding leads to a sharp decrease in yield compared with haymaking carried out at the time of flowering (Table 2).

The growth dynamics of the mass of one alfalfa stem in the second year of life, according to the main vegetative stages, were as follows: during flower buttons probing (5.3 g), during mass budding (11.1 g), during flowering (17.7 g), and at the beginning of seed formation (17 g). As can be seen, an

Table 2. Alfalfa hay yield based on the age of its systematic mowing (average data for 3–4 years).

Haymaking stages	Hay yield (t/ha by years)				Harvesting (from 1 ha)	
	1	2	3	Total for three years	Feed units	Digestible protein (kg)
Flower buttons probing	4.23	7.85	8.39	20.48	11060.0	2714.3
Mass budding	5.04	9.91	11.23	26.18	16614.0	3560.5
Beginning of flowering	5.82	10.79	14.84	31.45	16354.0	4277.2
Mass flowering	6.14	12.93	15.67	34.75	17023.0	3578.9
Beginning of seed formation	5.96	7.78	10.54	24.28	13211.2	3252.5

intensive growth of green mass in Semirechensk alfalfa occurs in the stages of flower buttons' probing to the beginning of flowering. The second reason causing a decrease in the alfalfa mass yield, with its systematic harvesting in the early vegetative stages, is the thinning of plants. The chief reason for the high thinness of the alfalfa plant in experiments with annual haymaking in the early vegetative stages is a severe depletion of plants (Nurymov, 1995; Nurymov *et al.,* 1992).

During the pod formation, the nutrients in the roots decreased again, and with the beginning of seed maturation, the nutrients increased sharply again. Consequently, the systematic mowing of alfalfa herbage in the early vegetative stages leads to an intense weakening of plants, leading to their death. Thus, in the options performing mowing before flowering, the height of the stems 10 days after the haymaking was 10.6–12.4 cm, and when doing the mowing during the flowering period, it was 20.9–21.5 cm. According to past studies, it has been evident that it is possible to get three to five complete haymaking of alfalfa in irrigated areas for hay in the South and Southeast of Kazakhstan (Kvitko, 1990; Alimbetov, 1991; Zhunisbekov and Mamadalieva, 1997; Myrzabek, 1998).

Asanov *et al*. (1990) reported that the best time for mowing alfalfa is the stage of the beginning of budding. During this time, it contains the maximum nutrients, giving more haymaking and a high feed output per unit of forage area. Earlier mowing of alfalfa leads to a shortage of yield, and late mowing escorts to deterioration of the feed quality, decreasing yield. Thus, according to past research performed at the Kazakh Research Institute of Agriculture, Almaty region, Kazakhstan, mowing alfalfa in the budding stage resulted in four haymaking, with a total green mass yield of 60.6 t/ha, and on light chestnut soils, 71.4 t/ha, with three haymaking in the flowering stage, having yields at 51.9 and 60.9 t/ha (Velichko, 1990).

Kvitko's (1990) findings revealed that the mowing regime is crucial for long-term use of alfalfa. The first-year alfalfa needs mowing only at the flowering stage. However, an adequate amount of plastic substances that contribute to the formation of shoots accumulate in the crown. In its first year, alfalfa reaches the second flowering 45–50 days after 80 days from germination to flowering. In two haymaking, the yield of green mass was 22.8 t/ha, the yield of feed units was 4.8 t/ha, and the digestible protein was 0.83 t/ha.

In the second year of life, mowing alfalfa for the first time occurs in the budding stage. However, a delay significantly lessens the yield as the alfalfa overgrows and lodges. The second and third haymaking were best after 30–35 days at the beginning of flowering. Plant leaf coverage was 50%–60%, causing the protein yield to increase by 0.3–0.4 t/ha compared with harvesting in the full flowering stage. The optimal mowing interval between the first and second haymaking was 30–35 days, and among the second, third, and fourth haymaking, the interval was 35–40 days.

The quantity and quality of hay depend upon the harvesting time (Table 3). Figure 1 also shows a graph of the change in protein content, the construction considering the peculiarities of alfalfa weight gain according to

Figure 2. This graph - Q(t) is called a sigmoid curve, and by approximating it, obtaining the dependence in the form:

$$Q(t) = Q_m[1+\sin(Bt+3\pi/2)]2+\Delta Q\ ,$$

Where:
Q_m is the largest biological mass of alfalfa at the end of the biological process of weight gain; B is the approximation coefficient; t is the plant growth time; ΔQ is the unmown mass or the mass of alfalfa below the cutter bar of the mower. The production of alfalfa hay presents some critical aspects of the weather conditions during harvesting that can entirely affect the quality of the produced hay (Iannucci *et al.*, 2002).

By carrying out haymaking in the early vegetative stages, the subsequent regrowth occurs mainly from the axillary buds of the stem remaining after mowing. However, by harvesting during the flowering period, the regrowth transpires from the dormant and the root crown's additional buds. Therefore, the best time for harvesting alfalfa for hay is from the flowering start to full flowering, which covers around 11–12 days.

The justification of the number of haymaking can provide a set of maximum gross yield:

$$Q_{grossmax}=n_{opt}Q_{opt}$$

n_{opt} is determined by researching Q_{gross} for an extremum:

$$dQ_{gross}/dt=0$$

The number of haymaking n_{opt} is equal to:

$$n_{opt}\leq t_{seas}/t_1$$

Where:
t_{seas} is the length of the alfalfa vegetation period during the year; t_1 is the optimal timing of haymaking defined by the previous equation.

The main limitation of the timing of haymaking is:

$$t_b<t_1<t_e$$

Where:
$t_{b,\ te}$ are beginning and end of alfalfa flowering (Figure 2).

It follows from the above that the maximum yield of alfalfa depends on the number of haymaking, yield, and the harvesting duration. However, it is necessary to consider the agrotechnical requirements for alfalfa harvesting.

RESULTS AND DISCUSSION

On harvesting alfalfa, the prime focus should be on its highest gross yield, conserving the maximum yield, and enhancing the feed's nutrient content. Violations of harvesting technology and deviation from agrotechnical requirements significantly decline quality and increase losses in alfalfa during their haymaking, storage, and use (Ormandzhi, 1991). The leading rates of nutrient losses are available in Table 4. Since the alfalfa development stages change quickly, mowing transpired in a very short time to obtain high-quality hay. In the conditions of Kyzylorda region, where the weather is dry and hot, the necessary allotment is 10–12 days according to agrotechnical requirements.

Table 3. Hay yield and quality based on the time of harvesting the Semirechenskaya alfalfa (data on irrigation on average for four years).

Harvest time	Hay yield in the first year (t/ha)	Leaf coverage (%)	Content in hay (%)		
			Proteins	Fibers	Fats
Budding	13.46	48.6	18.34	15.12	1.57
Beginning of flowering	15.18	45.9	18.11	14.07	1.61
Full flowering	14.43	39.1	15.22	11.14	1.63
Beginning of pod formation	13.87	35.4	13.38	10.43	1.71

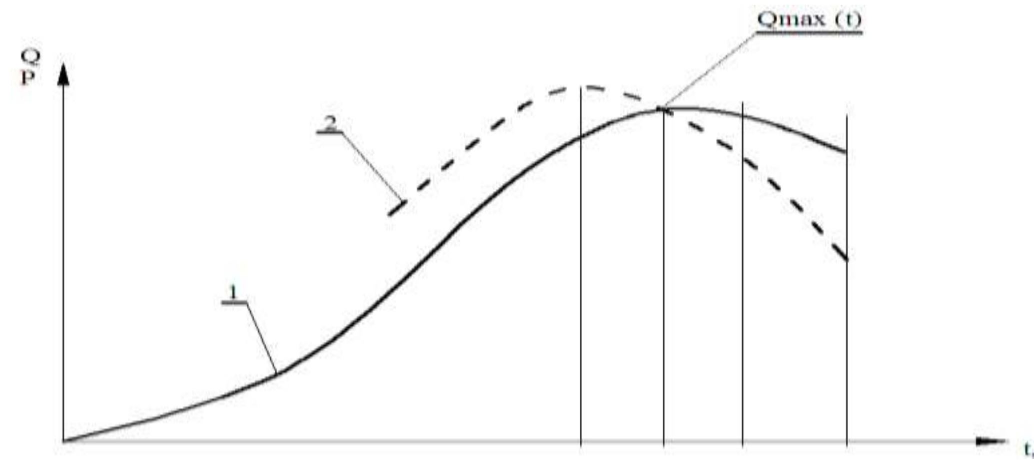

Figure 1. Graph of the change in protein content in alfalfa *(*Protein content P[t] 2 and weight gain, t, days*).*

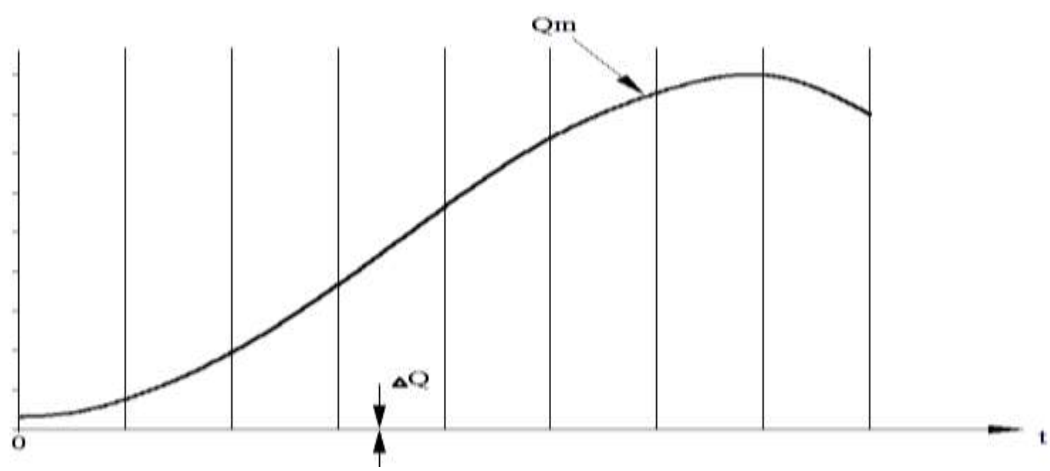

Figure 2. Dependence of alfalfa weight gain Q over time t (Q - weight, tons/ha; t - time, days).

Table 4. Nutrient losses of alfalfa hay during haymaking, storage, and distribution (According to Ormandshi, 1991).

Type of haymaking	Haymaking	Storage	Distribution	Total
Loose (%)	35-40	5	3	43-48
Pressed (%)	25-35	3	1	29-39

Mowing alfalfa is the most crucial practice in all technological operations. Therefore, cutting the plants should be even and complete. The height deviation along the entire length of the cutter bar should not exceed ±5 mm (Kepner *et al.,* 1978; Popov and Sechkin, 1979). Losses during mowing alfalfa caused by high cutting and uncut plants should not exceed 2%. Cutter bar shoes and wheels of units should not crush, cut, or uncut alfalfa. Mowing alfalfa requires placing them in windrows evenly along the entire length without gaps or piling up (Zhunisbekov and Mamadalieva, 1997; Kvitko, 1990). In areas with the most humid climate, loosened, turned-over grass needs an even spreading over the space, avoiding the creation of heaps, before keeping in swaths until the moisture content of the mass decreases to 60%, and then collecting it into consistent windrows up to 1.2 m wide (Popov and Sechkin, 1979).

In drying hay in windrows, it is more suitable to collect it along the mowing line using finger-wheel rakes, allowing the hay's raking across the swath using dump rakes, during which the total hay loss should not surpass 2.5%. Alfalfa drying in windrows must lower moisture content from 60% to 35%. The windrows need tedding and turning to 180° to achieve this, and when the moisture content is about 30%, its collection in shocks happens (Kepner *et al.,* 1978; Tyutyunichkov, 1982; Ormandzhi, 1991). However, Wills and Bledsoe (2015) recommended raking plants in the same direction as the cut to allow the rake teeth to make contact with the leafy part of the plant for better plant movement to roll the leaves toward the center of the windrow. They also reported that raking in the course opposite to mowing would result in the leafy part being on the outside of the windrow, which could result in more damage to the plant with any further mechanical impression. Hunt and Wilson (2016) suggested raking plants in the same direction as the previous mowing, considering the entire raking process needs completion before the moisture drops below 40%, especially for deciduous plants, such as, alfalfa.

The moisture content determination of the mowed mass of alfalfa used external features, i.e., the structure and color of the leaves and stems:

- At the moisture content of the mowed mass (50%–70%), leaves occurred wilted, with their color faded; however, the stems were fresh and green;
- At 40%–50%, the leaves were still soft, the stems appeared wilted, and their color had faded;
- At 30%–40%, the leaves start to deteriorate, the stems were still flexible, the grass color faded, and the petioles of the leaves start to break, with a real danger of losing dry mass:
- At 25%–30%, the leaves dried out in a crumbling position, sap released from the stalks, and the leaf petioles were very fragile, with more loss of dry mass:
- At 20%–25%, the stems are still soft but not releasing the sap from them, the leaf petioles were very delicate, and the loss of dry mass is significant;
- At less than 20%, the stems were brittle, the fracture was straight, the leaf petioles occurred very brittle, and the loss of dry mass was very high (Ormandzhi, 1991).

In alfalfa, for a more accurate determination of the moisture content, it is necessary to take 2 kg of new-mown grass from the windrow and spread it with a layer of the same thickness as the swath. Such areas require laying at every 10 swaths, with the moisture calculated as follows (Hunt and Wilson, 2016):

$$W = 100 - PK/P_{n,}$$

Where:
P is the initial grass weight in kg, K is the dry matter yield (%), and P_n is the weight of the dry grass (kg).

Alfalfa haymaking proceeded in loose and pressed forms. Loose alfalfa hay creation continued by drying the mowed mass in windrows, picking it up, transporting it to the storage sites, stacking, and cocking. Making loose alfalfa hay must observe specific agrotechnical requirements. By picking up windrows, the pick-up mechanism should follow well the field surface and not clog the alfalfa hay with earth. Transporting alfalfa hay to the place of stacking should not use rope sweeps so as not to infect the alfalfa hay with earth and not to lose leaves.

For alfalfa haymaking, the optimum moisture of stacking, picked up by spring-finger pickups, was 25%–30%. Raking alfalfa hay with front-end loaders requires optimal moisture between 25%–28%. With less moisture, raking alfalfa from windrows into a pile must be in the morning or evening in the dew. In this case, the total yield losses will not exceed 2% (Kulik, 1978; Baymbetov, 1982; Ormandzhi, 1991). Stacked alfalfa hay should have an optimal moisture content of 20%–22%. The hay must have a standard moisture (a 16%–17% recommended moisture to stack in the early morning or before sunset in the dew) to avoid loss. Dry hay storing for a long time needs tightly stacking in a haystack and tamped.

The stack base width, height, and length should be 6–8, 8, and 10–20 m, respectively, based on the hay amount. In preventing the stack from getting wet to a depth of more than 0.25 m, it is obligatory to tamp it well and form two slopes with an angle of 90°–100°. Avoiding the wind to blow up the hay requires covering the top of the stack with a waterproof material, fixed to logs 10–15 cm in diameter, and bound together with a steel wire (Popov and Sechkin, 1979). Making alfalfa hay by shocking, the moisture content should be 20%–30%, and with cocking (20%–22%). Approximating the moisture content determined visually showed the hay's color and physical and mechanical properties. However, if the moisture content is high, the weight of the shock should not exceed 400 kg; if the moisture content is low (25%), the stock should not exceed 600 kg. The shock density must be at least 70 kg/m. A stock formation can be up to 7 tons with a hay moisture content of 20%. Shocks should have a regular, complete shape and slopes on both sides. During storage, the wind must not destroy the stocks, with the stocks not getting soaked to a depth of more than 0.2 m.

Stacked for storage helped determine the quality of alfalfa hay by color, odor, moisture content (17%–18%), and the time of grass mowing. By making pressed alfalfa hay, such works as picking from windrows, pressing into bales, and transportation to storage sites in stacks proceeded. The chief agrotechnical requirements for hay pressing are as follows: during the mass picking from the windrow, baling, the transport of supply or unloading in the field, the baler's work tools should not grind hay and scatter leaves and grass inflorescence. Hay balers are specific agricultural machinery designed to collect harvested hay from windrows and press it into round or square bales. The baling process follows three previous operations, namely, cutting the feed with mowers that cut the feed and unloading it in rows, windrowing with a mower that collects the cut feed into larger windrows (1.0–1.5 m wide), and the raking process using rakes that mix and turn the hay to ensure a complete hay drying (Kepner *et al.,* 1978).

The Aral Sea region of Kazakhstan is a hot climate area; therefore, hay baling is best in the morning or evening so as not to lose the most valuable parts of the plants. The density of pressing hay into bales should be uniform, indicated by weather conditions, with the mass moisture at 100 to 200 kg/m^3. In practice, the density of baled hay with the mass moisture (20%–22%) can be 150–200 kg/m^3. However, the bales need immediate loading into vehicles and transporting them onto the storage sites. If the pressed hay from windrows has 25%–30% moisture content, the pressing density should be 130–140 kg/m^3. At the same time, the bales should have dried in the field before transporting them to the storage site.

The acceptable density of pressing alfalfa hay into bales is 35 cm × 45 cm × 85 cm, depending on its moisture content in different zones (Table 5). Overall, the dimensions of bales had the following limits, i.e., length, width, and height of 0.7–1, 0.5, and 0.36 m, respectively. These basic sizes with a specific shape are necessary to maintain during loading into vehicles, transporting, and stacking for long-term storage. Binding pressed bales consisted of two steel wires with 1–2 mm diameter placed in parallel with the same compressive force of the mass. The non-binding of bales by the binding unit should not exceed 2%. Losses of alfalfa hay during its pickup from the windrow, baling, and delivery by transport should not exceed 2%. The losses of leaves and inflorescences are also unallowable. According to agrotechnical requirements, the dimensions of stacks of baled hay should be as follows: with length, width, and height of 20, 5–5.5, and 18–20 m, respectively. The optimal dimensions of a stack are available if the weight of the bales ranges from 40 to 60 tons.

Table 5. Permissible density of pressing alfalfa hay into bales (35 cm × 45 cm × 85 cm) based upon its moisture content in different zones.

Hay moisture (%)	Semi-desert zone, southern part of forest steppe		Forest zone, northern part of Forest steppe	
	Pressing density (kg/m^3)	Bale weight (kg)	Pressing density, (kg/m^3)	Bale weight (kg)
Up to 20	Any	30 and above	Any	30 and above
20-22	Same	30 and above	180-200	26-28
23-25	100-210	26-29	160-180	23-25
26-28	170-190	23-26	140-180	20-22
29-31	150-170	20-23	120-140	17-18

The agrotechnical requirements for transporting alfalfa pressed bales are as follows: the baler should provide 100% pick-up of standard bound bales with a pressing density of at least 100 kg/m^3 and with a weight up to 40 kg, having an angle of rotation of the longitudinal axis to the movement direction within ±20°. The stockpile formed on the vehicle should not fall apart and have the correct geometric shape during transporting and stacking at the place of long-term storage. Work tools of the truck should not damage the binding wire on the bales. During loading onto the vehicle and unloading of bales from it, the losses should not exceed 0.1%; however, in transporting pressed bales, losses are unallowable (Tyutyunichkov, 1982; Ormandzhi, 1991).

According to the established agrotechnical requirements, harvesting alfalfa should proceed at the budding stage to obtain high-quality silage with minimal losses. The silage mass needs an even leveling with its continuous compacting by filling the storage. The thickness of the layer laid per day should be at least 0.8–1.2 m in trenches and 4–5 m in silos (Kulik, 1978; Hunt and Wilson, 2016). The temperature of well-compacted mass should not exceed 30°C to ensure a normal ensilage process. A slow storage filling and insufficient compacting may lead to a large amount of air between the particles, causing the mass temperature to rise to 60 °C–80 °C, developing butyric acid bacteria and other harmful microorganisms. The contamination of the silage mass with fuel, lubricants, and soil also requires strict avoidance.

Storing the silage mass should have various capacities for 3–4 days without interruption. After filling the storage, its immediate covering is crucial to isolate it from air and precipitation. Delaying covering for 2–3 days increases feed losses by 7%–10% due to warming by increased temperature of the entire mass. If the requirements of alfalfa silaging technology because of fermentation are visible, the total loss of dry matter should not exceed, in silos - 8%, in large-capacity trenches (8%–12%).

The haylage-making process includes the following operations: alfalfa mowing, crushing, wilting, placement in storage, and unloading from storage. By performing these operations, it is utmost to comply with agrotechnical requirements so that the haylage contains sufficient nutrients, is not acidic, has the same amount of sugar as new-mown grass, and animal consumption for high digestibility.

For haylage making, mowing alfalfa is best in the stage - from the beginning of budding to the beginning of flowering. The mowing duration should not exceed 10 days, and the optimal cutting height must be 4–6 cm. Crushing is simultaneous with mowing in settled good weather and during irregular rains. Partially and completely crushed plants should be at least 90% of the total mass. Depending on the weather conditions, the wilting process lasts from two to 48 hours. Grass wilts in swaths at 60%–70% moisture content and windrows up to 55%–60% (Wills and Bledsoe, 2015).

Plant mass pickup must progress when moisture drops to 55%–60%. Chopped plants up to 20 mm long require placing in silo. Plants with this length should be at least 75% of the total mass. In preserving feed in trenches, a cut length of up to 15 mm is allowable. With their sides well extended, maximize the use of the carrying capacity of vehicles when transporting crushed grass. Losses during mass overloading should not exceed 1%. The optimal duration of placing haylage in trenches was no more than four days and in silos (3–4 days) without interruption. Placing the mass in the trench continuously compacts it. The inner layer temperature should not exceed 37 °C during the trench filling. However, if that temperature increases, the placing process must accelerate with strengthened tamping. Haylage with a moisture content of 50% needs essential placing with a volume weight of 450–550 kg/m^3.

When completing the placing of haylage, covering the trench surface with a film on top included a quicklime 5–10 mm thick, shredded straw with a layer of 20–30 cm, and poured earth 15–30 cm thick. Annually in trenches, selected haylage results in vertical layers with a thickness of at least 50 cm, in silos, at least 30 cm over the entire open surface. In silos with bottom discharge, the one-time discharge volume was unlimited (Zangiev *et al.,* 1999; Zhunisbekov *et al.,* 2000). Compliance with all the above agrotechnical requirements also ensures the reduction in material and financial expenses for harvesting the alfalfa with good quantity and quality.

CONCLUSIONS

Alfalfa is one of the valuable forage crops in forage crop production in the Kyzylorda region, Kazakhstan. It is the chief ameliorative plant in the rice-crop rotation. According to the regional program for diversification of crop production, as well as, with the increased number of farm enterprises in the region, the alfalfa crop area sought to be more than 40,000 to 60,000 hectares, with an expected increase of 25%–30%. In the cultivation of alfalfa crops, the most critical operations comprised the mowing, bailing, loading, and transporting, which account for more than 70% of all minimum and labor costs. Optimization of alfalfa harvesting reduces losses of 25%–30% while maintaining its nutritional properties. It has been evident that the uncoordinated work of the units performing the operations of mowing, bailing, loading, and transporting alfalfa causes up to 40% loss of shift time, with the technical and economic indicators reduced to 25%–30%, as well as, the nutritious properties of alfalfa. Improving the efficiency of the used units was successful for all the crops grown in the Kyzylorda region, Kazakhstan.

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