Studying the Technology of Cultivating Mixed Forage Crops in the Area of Dry Steppes of the Western Kazakhstan

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Since 2012, the state program “Agribusiness 2020” for development of agribusiness has been in effect in the Republic of Kazakhstan. One of the tasks of this program is to increase the export of meat up to 16,000 tons per year. Taking into account international experience and conditions of Kazakhstan, the KazAgro Holding has developed and obtained approval from the Head of the State for the “Development of Cattle Meat Export” project. In five years, in the Republic of Kazakhstan it is planned to build up to 60 feeding stations with one-time content of 150,000 animals, or 300,000 animals per year. It will make it possible to produce about 60,000 tons of beef for export in five years, and 180,000 tons in 10 years. At present, young cattle is fattened and grown in fattening complexes that use extensive method of using unbalanced diets, which leads to high cost of forage and labor per unit of growth. Therefore, one of the important conditions for further increase in beef production is developing efficient technologies for ensuring own forage supply for fattening complexes and farms with saving forage grain. The aim of the research is to develop a technology that would ensure manufacturing of protein-balanced forage in the conditions of fattening complexes and farms of industrial type. The research made it possible to obtain data that allow assessing productivity of mixed forage crops with various harvesting time for using them in the production of own forage at fattening complexes and farms of industrial type in the conditions of the Western Kazakhstan region. The nutrition regimes for mixed forage crops by adjusting time and norms of mineral fertilizers introduction have also been found as a result of the research.

Keywords: Fattening complexes, mixed agrophytocenosis, productivity, forage crops, protein, metabolic energy, mineral fertilizers.

Research background

The President of the Republic of Kazakhstan N. A. Nazarbayev in his address to the nation “Building Future Together” has stated a strategic task for the implementation of an unprecedented project in development of livestock breeding. By 2016, the agrarians of the Republic are to export 60,000 tons of meat. While 20 years ago Kazakhstan exported over 180,000 tons of meat, in 2009 it exported only 300 tons. This is an evidence of huge locked potential of livestock breeding. It is especially important, since close to us there is the huge Russian market that imports about 1.5 million tons of meat every year. Moreover, thanks to the Customs Union created at the initiative of the Head of the State, barriers have been eliminated, licensing...
procedures have been simplified, veterinary norms have been unified between our countries, thus creating all necessary conditions for increasing export. Our Republic has all the prerequisites for developing beef cattle breeding, including the availability of natural forage lands and unused arable land and low-cost pasture technology of beef cattle breeding. Besides, livestock breeding is a traditional craft of the ingenuous population. All this creates the potentiality for establishing Kazakhstan as a significant and competitive player in the global market (Nasiev et al., 2014).

At present, the bulk of slaughter livestock comes to meat processing factories from farms and complexes of industrial drive where calves are grown and fattened on own forage. In the majority of households, calves are grown extensively on unbalanced rations, which fact leads to significant cost of forage and labor per unit of growth. Poor feeding and poor animals keeping conditions during the growth and fattening period lead to the fact that calves reach live weight of 250-300 kilograms only at the age of 17 to 18 months, after which they are sent for further fattening to specialized fattening farms and complexes. The under-grown and underdeveloped calves do not fully compensate for this lagging behind by increasing the live weight in the final period of production, i.e., fattening. The cost of forage per 1 kg of the gained weight in fattening such animals grows significantly. Therefore, one of the important conditions for further increasing of beef production is the development of efficient technologies for ensuring own food supply for fattening complexes and farms with saving forage grain. (Vavzhynchak, 2013; Devyatkin, 2012; Karasek, 2008).

**Substantiation of the research area**

Vegetable forage is the basis of a reliable forage base. It constitutes about 95% of the total forage consumption. The main source of vegetable forage is field forage production. It provides over 70% of the total amount of forage, and in the areas with high ploughness of agricultural land - up to 90-95% (Novoselov, 2008; Tarasov, 1997).

Cultivation of mixed forage crops plays an important role in improving accumulation rate of forage protein. Many years of scientific research and industrial practice indicate that plants in mixed planting are more adaptable to environment changes, as compared to planting separately. It can be explained by the fact that kinds and grades of the same specie react differently to soil-and-climate environment. In mixed planting, plants use main factors of growth and development, primarily moisture and solar energy, more evenly, and to a fuller extent. Having different requirements to nutrition and moisture, various species of plants in mixed planting consume these factors from various horizons, not competing with each other. For example, legumes, having a stock root system, extract nutrition and water from deeper layers of soil, while cereals extract these from upper layers. The roots of legumes tolerate hardly soluble compounds of phosphorus from deeper layers of soil, and turn them into other forms available for other species. Legume bacteria that live on the roots of legumes adopt air nitrogen, which is used by other plants sown together with them. Besides, mixed crops in the majority of cases ensure obtaining forage with better content of nitrogenous and non-nitrogenous substances. Efficiency of mixed crops is manifested by works of scientists from neighboring countries and beyond. The authors believe that mixed crops of legumes with poaceae feature high efficiency; they not only make it possible to solve the problem of enriching forages with digestible protein, but also to create the conditions for increasing the overall productivity of forage crops (Blagoveschenskaya, 2004; Bondarenko, 1986; Elsukov and Tyutyunnikov, 1999, Christiansen et al., 2000).

According to the studies performed in various countries, even such order grains as barley, when harvested for mono forage, do not satisfy zootecnic standards for animal forage. However, their combination with high-protein components provides a real possibility to obtain highly nutritional and balanced corn-and-hay forage. Many years of scientific and production experience confirm that mixed planting of forage grain species with legumes makes a good raw material for high-quality forage with high nutritional value. The mixture of barley with chickpeas ensures obtaining grain-and-hay forage, rich in protein, with sufficient content of sugar. In cultivating a mixture of barley and chickpeas,
accumulation rate of protein depends on the time of harvesting. In forages made of mixtures harvested in the phase of milky wax ripeness, sufficient content of digestible protein is detected. In haylages, the content of digestible protein in one forage unit was 115 g, which is 28.6 g higher than in case of traditional time of harvesting. Many researchers propose to harvest haylage from mixtures of annual crops (barley+chickpea) and harvest directly by combined harvesters in the phase of milky wax ripeness. In earlier or later periods, the yield of nutrients from 1 ha decreases. The nutritional value of forage decreases, too. According to three-year data, the yield of dry matter in the milky wax ripeness phase of a mixture of barley and chickpeas, as compared to milky ripeness of corn, increases from 25.1 to 38.9 hwt/ha, that of protein - from 371.3 to 494.2 kg/ha (Zhuchenko and Ursul, 1983; Kislov, 2007; Nasiev, 2013; Burns, 2011; Terkamp, 2003).

The main reasons for choosing barley and chickpeas for mixed crops are their biologic characteristics (adaptivity and draught tolerance), therefore the acreage of barley and chickpeas has been increasing in the recent years. It is also associated with diversification of crop production (reduction of wheat acreage and increasing the share of forage crops).

Optimization of nutrition regimes by using mineral fertilizers is also important in increasing productivity and quality of forage crops. In the experiments, the use of fertilizers significantly increased the yield of intercropped forage crops (Yatsenko, 1999, Tsybulko and Paziy, 1985; Nehring and Luddecke, 2001; Muller, 2002).

In the context of mixed crops, research was performed in many countries; however, experiments with using mineral fertilizers for forage crops in the conditions of the research area have not been performed until now.

**METHODS**

The research was conducted in the West Kazakhstan Agrarian Technical University named after Zhangir Khan in 2012-2014 (Republic of Kazakhstan, Uralsk).

The soil in the plot was dark brown loamy and silty; the content of physical clay in the arable horizon was 51%. The arable horizon of the soil contains 2.8 to 3.1% of humus. Accumulation of carbonates starts in the bottom part of horizon B and reaches its maximum in horizon SK at the depth of 70-80 cm. The sum of absorbed basis in the 0-10 cm layer is 27.8 to 28.0 mg.equiv. per 100 g of soil. Down to the depth of 80 cm, Na prevails; Mg prevails in deeper layers. The content of Na in the arable and sub-arable horizons is low, 3.1 to 3.6% of the total absorbed basis. The 1.5-meter layer of soil contains (PV) 672.5 mm of moisture, and retains (NV) 481.3 mm, out of which productive (DAV) is 236.7 mm, and in the arable layer - 160.8, 102.1 and 57.6 mm, respectively. Bulk density of soil varies between 1.22 to 1.28 g/cm³ arable layer, and 1.65 to 1.66 g/cm³ at the depth of 80-120 cm.

According to the morphological characteristics of genetic horizons of the profile and the agrochemical characteristics of the arable layer, the soil of the experimental plot is characteristic for the dry steppe zone of the Western Kazakhstan.

Plots area was 50 m², the experiment was repeated three times, and the plots were located randomly. The generally adopted methods of cultivating forage crops was used, and the species were zoned for the Western Kazakhstan region.

In performing field experiments with legumes, accounting for and observation of phenological phases and growth of forage crops was performed according to the standard methods (Methodical Guidelines, 1987).

Photosynthesis of forage crops was studied according to the standard methods (Nichiporovich et al., 1961).

Definition of the main photosynthetic indicators by crops development phases. The area of a single leaf surface was calculated according to the formula of Anikeev-Kutuzov: AR=2/3p*h, where p is the width of the leaf, cm; h is the length of the leaf, cm. Harvesting and yield was accounted by continuous method, followed by reduction to standard humidity.

Statistical processing of the research results was made by the method of dispersion analysis with the use of computer software (Dospekhov, 1985).

Chemical composition of the plant mass
and exchange energy were assessed according to the generally adopted methods (Methodical guidelines 1989).

In the whole, the weather conditions of years 2012 to 2014 are considered dry. While the average height of precipitation in the region for the years of the research was 311 mm, within the years of the research, the amount of precipitation did not exceed the average long-term rate. If precipitation for the warm months from April to August is summarized, the lack of precipitation for this period in Uralsk was 21.0 millimeters (with the many years figure of 143.0 mm). The temperature also varies throughout the year. For the period from April to August, the average air temperature was 21.23 °C. The analysis of air temperature and precipitation correlation shows that the whole of the summer period was arid, with peak in the period between June and August. In the period between mid-May to mid-June, increased temperature and deficiency of precipitation was observed, which caused a gradual decrease in moisture reserves in soil, which, in turn, affected growth and development of forage crops.

The recognized varieties of forage crops were used in the research: the Donetsky 8 barley, and the Yubileyny chickpeas.

The norm of seeding crops in mixture is 50% of the full norm. The norm of seeding barley is 2500 million fertile seeds, that of chickpeas - 40 thousand fertile seeds per 1 ha.

Green forage was harvested in the phase of the beginning of barley flowering - June 18.

Corn-and-hay forage was harvested 2 times: in the phase of milky ripeness of barley - on June 27, and in the phase of milky wax ripeness of barley - on July 2.

Corn forage was harvested in the phase of full ripeness of barley - on July 7.

In the experiment of optimizing nutrition regimes for mixed forage crops, the following mineral fertilizers were studied: ammonium nitrate and double superphosphate.

**RESULTS AND DISCUSSION**

**Photosynthetic activity of forage crops**

Creating valuable forage for developing livestock production depends on correct composition of crops, and on the time of harvesting these crops. Therefore, in accordance with the purpose of the research, we studied peculiarities of forming productivity of mixed plantings of barley and chickpeas at various times of harvesting in the conditions of the dry step area of the Western Kazakhstan region.

For obtaining full-fledged forage, the area of leaves should be rather large, which has paramount importance for the intensity of the photosynthesis process. In the options of the research, the largest leaf area was noted in the option of a mixture of barley and peas harvested in the milky wax ripeness for corn-and-hay forage, which was equal to 26.44 thousand $m^2/ha$, the photosynthetic potentially of this agrophytocenosis was also the highest and was 1.30 million $m^2/day/ha$.

When compared to other options, the least area of leaf surface - 16.72 thousand $m^2/ha$, and, correspondingly, the low level of photosynthetic potentiality - 1.15 million $m^2/day/ha$ was in the option of separately planted barley.

When the mixture of barley and chickpea was harvested in the phase of full ripeness for corn forage, the area of leaves surface was 24.68 thousand $m^2/ha$, with photosynthetic potentiality of 1.2 million $m^2/day/ha$.

When the mixture of barley and chickpea was harvested in the phase of chickpeas flowering, the area of leaves surface was 22.62 thousand $m^2/ha$, with photosynthetic potentiality of 1.8 million $m^2/day/ha$. The indicators of photosynthetic activity of barley and chickpeas were higher when they were harvested in the phase of barley milky ripeness - the area of leaves was 23.88 thousand $m^2/ha$ and the photosynthetic potentiality was 1.19 million $m^2/day/ha$ (Table 1)

**Assessment of forage crops productivity**

The ultimate goal of cultivating certain crops is obtaining a product. With that, not only the physical weight of the product, but also assessment of its nutritional value is very important for forage. For the forage purposes, not only single crops are interesting, but the use of mixed forage crops, as well. Correctly selected mixed crops make it possible to obtain balanced products for forage.

The research of mixed crops with various times of harvesting provided the following
data about the productivity of agrophytocenoses: the yield of green mass in the option of joint planting of barley in chickpeas harvested in the phase of chickpeas flowering (for green forage) was equal to 72.58 hwt/ha, which, in terms of dry mass was 12.95 hwt/ha. (Table 2)

In the option of joint planting barley and chickpeas for corn-and-hay forage (harvested in the phase of milky ripeness of barley), the productivity of the green mass was 92.18 hwt/ha, and that of dry weight - 18.94 hwt/ha. In the option of planting barley + chickpeas harvested in the phase of milky wax rightness (for using as corn-and-hay forage) these indicators were equal to 85.45 and 20.13 hwt/ha, respectively. Corn yield in case of separate planting barley (reference) and a mixture of barley and chickpeas for using as corn forage was 16.80 and 20.45 hwt/ha, respectively.

**Mixed crops nutritional value depending on time of harvesting**

Industrially important summarized indicators of forage usefulness are accumulation of forage units, digestible protein, and forage protein units in the harvest. The comparative test of various times of harvesting for mixed crops made it possible to identify the most nutritionally valuable mixtures in terms of the yield from a unit of area of forage units and crude protein. So, during the research, the highest yield of product in terms of forage units and crude protein was obtained in the option with using barley and chickpeas harvested in the phase of full ripeness (for corn forage) (21.16 and 4.05 hwt/ha, respectively), the yield in the option when the mixture of barley and chickpeas was harvested in

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**Table 1.** Indicators of photosynthetic activity of mixed agrophytocenoses at various times of harvesting in the dry steppe area of the Western Kazakhstan

<table>
<thead>
<tr>
<th>Options</th>
<th>Leaves surface area, thousand m²/ha</th>
<th>Photosynthetic potential million m²/day/ha.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley for grain forage (reference)</td>
<td>16.72</td>
<td>1.15</td>
</tr>
<tr>
<td>Barley + chickpeas (harvested for green forage in the beginning of chickpeas flowering phase)</td>
<td>21.62</td>
<td>1.18</td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley milky ripeness)</td>
<td>23.88</td>
<td>1.19</td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley milky-wax ripeness)</td>
<td>26.44</td>
<td>1.30</td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley full ripeness)</td>
<td>24.68</td>
<td>1.20</td>
</tr>
</tbody>
</table>

**Table 2.** Productivity of forage crops at various times of harvesting in the dry steppe area of the Western Kazakhstan

<table>
<thead>
<tr>
<th>Options</th>
<th>Corn hwt/ha</th>
<th>Green mass hwt/ha</th>
<th>Dry weight hwt/ha</th>
<th>Forage units, hwt/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley for grain forage (reference)</td>
<td>16.80</td>
<td>-</td>
<td>-</td>
<td>16.44</td>
</tr>
<tr>
<td>Barley + chickpeas (harvested for green forage in the beginning of chickpeas flowering phase)</td>
<td>72.54</td>
<td>12.95</td>
<td>11.01</td>
<td></td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley milky ripeness)</td>
<td>92.18</td>
<td>18.94</td>
<td>17.62</td>
<td></td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley milky-wax ripeness)</td>
<td>85.45</td>
<td>20.13</td>
<td>19.53</td>
<td></td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley full ripeness)</td>
<td>20.45</td>
<td>-</td>
<td>-</td>
<td>21.16</td>
</tr>
</tbody>
</table>

LSD$_{0.05} = 1.85$ hwt/ha
the phase of milky-wax ripeness (for corn-and-hay forage) was a little lower - 19.53 hwt/ha of forage units, and 3.98 hwt/ha of crude protein (Table 3).

Table 3. Forage value of agrophytocenoses at various time of harvesting in the dry steppe area of the Western Kazakhstan

<table>
<thead>
<tr>
<th>Options</th>
<th>Crude protein hwt/ha</th>
<th>Suppl.to prot. unitg</th>
<th>Exchange energyGJ/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley for grain forage (reference)</td>
<td>1.78</td>
<td>108.2</td>
<td>14.81</td>
</tr>
<tr>
<td>Barley + chickpeas (harvested for green forage in the beginning of chickpeas flowering phase)</td>
<td>2.35</td>
<td>213.4</td>
<td>15.38</td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley milky ripeness)</td>
<td>3.64</td>
<td>206.6</td>
<td>20.84</td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley milky-wax ripeness)</td>
<td>3.98</td>
<td>203.8</td>
<td>19.21</td>
</tr>
<tr>
<td>Barley+chickpeas (harvested for grain forage in the phase of barley full ripeness)</td>
<td>4.05</td>
<td>191.4</td>
<td>22.22</td>
</tr>
</tbody>
</table>

17.62 hwt/ha, and that of crude protein - 3.64 hwt/ha. When a mixture of barley and chickpeas is used at fattening complexes as green forage (harvested in the phase of chickpeas flowering), the accumulation rate of forage units and crude protein at the level of 11.01 and 2.35 hwt/ha is ensured. In the reference option (barley), the accumulation rate of forage units was 16.44 hwt/ha, with crude protein yield of 1.78 hwt/ha.

By the presence of protein in the forage units, we distinguished the option where barley and chickpeas were combined in harvesting for corn-and-hay forage (in the phase of milky ripeness) - 206.6 g, and that for green forage (in the phase of chickpeas flowering) - 213.4 g. The level of protein presence in forage units was slightly lower in the options where barley and chickpeas were harvested in the phase of milky wax ripeness of barley (203.8 g) and harvested for corn forage (full ripeness) (191.4 g). This indicator was comparatively low in the reference option with separate barley (108.2 g).

High level exchange energy was characteristic for the option of a mixture of barley in chickpeas used for a corn forage, and harvested in the phase of full ripeness of barley - 22.22 GJ/ha.

In the options where the mixture of barley and chickpeas was harvested in the phase of milky and milky wax ripeness, the accumulation rate of exchange energy was approximately at the same level - 19.21 and 20.84 GJ/ha.

Low level of exchange energy was in the option where barley was combined with chickpeas and harvested early for green forage (15.38 GJ/ha), and in case of separate planting of barley - (14.81 GJ/ha).

Dependence of the yield and product quality on methods of adjusting nutrition regimes for forage crops

The study of mixed plantings at various norms and times of introducing mineral fertilizers provided the following data about agrophytocenoses productivity: the yield of corn forage mass in the option of joint planting of barley in chickpeas with introduction of fertilizers in the autumn in the dosage N_{30}P_{30} was equal to 20 hwt/ha.

In the option of joint planting of barley and chickpeas with row fertilizing in the dosage of N_{20}P_{20}, the productivity of corn forage mass was 23.44 hwt/ha. In the option where barley and chickpeas were sown with introduction of fertilizers in the autumn and in the spring in the dosages N_{30}P_{30}+ N_{20}P_{20}, this indicator was equal to 24.14 hwt/ha. The corn yield in case of single-species growing (reference) of a mixture of barley and chickpeas without fertilizers was 20.85 hwt/ha. (Table 4)
Comparative testing of various times of introducing mineral fertilizers for mixed plantings of barley in chickpeas made it possible to identify the most nutritionally valuable mixtures in terms of the yield of forage units and crude protein from a unit of area. So the research showed the greatest yield of product in terms of forage units and crude protein in the option where fertilizers were introduced in the autumn and in the spring in the dosages N$_{30}$P$_{30}$ + N$_{20}$P$_{20}$ (25.35 and 5.05 hwt/ha, respectively). Introducing fertilizers in the spring when sowing a mixture of barley and chickpeas ensured the accumulation rate of forage units at the level of 24.38 hwt/ha and crude protein of 4.80 hwt/ha. When a mixture of barley and chickpeas was used for corn forage with the introduction of mineral fertilizers in the autumn in the dosage of N$_{30}$P$_{30}$, the accumulation rate of forage units and crude protein was ensured at the level of 22.81 and 4.48 hwt/ha. In the reference option (without fertilizers), the accumulation rate of forage units was 21.69 hwt/ha, with crude protein yield of 4.15 hwt/ha.

By the presence of protein in forage units, the variant was identified where barley and chickpeas were combined with row-by-row introduction of mineral fertilizers in the dosages N$_{30}$P$_{30}$ + N$_{20}$P$_{20}$ in the autumn and spring (197.2 g). The presence of protein in forage units was slightly lower in the options where fertilizers were introduced into barley and chickpeas in dosages N$_{30}$P$_{30}$ after sowing (197.0 g), and N$_{30}$P$_{30}$ in the autumn (196.4 g). This indicator was comparatively low in the reference option with separately grown barley (191.4 g) (Table 5).

High-level exchange energy was characteristic for the option of mixed sowing barley and chickpeas with introducing mineral fertilizers in the autumn and in the spring into rows according to the scheme N$_{30}$P$_{30}$ + N$_{20}$P$_{20}$ - 26.80 GJ/ha.

In the options with combination of barley and chickpeas with introducing mineral fertilizers in the autumn and spring separately, the accumulation rate of exchange energy was approximately at the same level - 25.55 GJ/ha and 24.25 GJ/ha.

Low level of exchange energy was detected in the reference option of barley and chickpeas combination (22.73 GJ/ha).

CONCLUSION

Thus, in the dry steppe area of the Western Kazakhstan region it is advisable to use a combination of crops of barley and chickpeas for own production of green forage (in green conveyors), corn-and-hay forage, and corn forage.

For the production of corn-and-hay forage, it is necessary to harvest the mixture in the phase of milky wax ripeness of barley. In the green conveyors, the mixture should be harvested in the phase of chickpeas flowering. When the mixture is used for the production of corn forage, it should be harvested in the phase of full ripeness of barley. To increase the productivity of mixed plantings of barley and chickpeas, it is advisable to introduce mineral fertilizers for barley and chickpeas mixture in the dosage of N$_{30}$P$_{30}$ in the autumn and N$_{20}$P$_{20}$ during sowing.

In general, implementation of the obtained scientific data will make it possible for agriculture producers to enter new markets with quality product, which, in turn, will allow raising the rating of the country in the global market. Implementation of the project is especially important for enterprises included into the country industrialization map according to the forced industrial and innovation development program in the Republic of Kazakhstan. The obtained material will complement scientific information for developing a system of rational, cost-effective beef production with the use of own forage, and can be used both for developing design and technological norms and parameters for building complexes, and in practical operation of industrial type enterprises for growing and fattening young cattle. Implementation of the project is especially important for increasing productivity of agricultural companies and farmers that participate in the program of supporting agriculture “Agribusiness 2020”.

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