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Cultivation Technology and Efficiency of Field Bean Grain Usage in the Diet of Dairy Cows

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ABSTRACT: The research was carried out with the purpose of studying the influence of the sowing period and agrometeorological factors on the formation of grain yield of field beans in the nonblack soil zone in Western Siberia. It analyze the effect of the use of compound feed with field bean grain in the diet of dairy cows on their productivity. The study showed that early sowing on May 10-15 creates optimal conditions for ripening and formation of the field bean grain yield, as well as high protein content in it. Field beans sown on May 10-15 ripened in all years in 100% of cases and provided the highest yields (2.81-3.0 t/ha) and protein content in grain 27.7-28.3% and therefore, the highest total amount of protein, as confirmed by the results of industrial studies. The use of field beans in the diet of dairy cows instead of peas increases quality and yield of milk. At the same time, the profitability of milk production increases with the growth of animal productivity. Therefore, to increase the productivity of dairy cows, it is necessary to include field bean grain in the feed along with peas and to use a vibrating fresh feed mixer to increase the quality and uniformity of the prepared feeds. The description of the device and the principle of operation are described in the paper. A review and analysis of its interchangeable working parts and methods of their fastening in a vibratory chute are also provided. The results of theoretical and experimental substantiation of the main kinematic parameters of the mixer are presented. In connection with the increase in the sown area of leguminous crops, including a new Siberian fodder variety, it is important to study the possibilities and methods of cultivating them to obtain stable yields and quality, as well as the use of fodder beans in the diet of dairy cows in the composition of animal feed. The research results show that the contribution of this scientific work allows increasing the profitability of milk production.

Keywords: field beans, grain yield, protein content, dairy cow productivity, compound feed, vibration mixer, mixing element, kinematic parameters.

I. INTRODUCTION

An analysis of factors influencing the milk production of animals shows that the main ones are feed quality (30%) and changes in the feeding ration (17%) [1]. As global experience shows, 60% of the solution for the challenge of increasing productivity is the feeding level and full value condition of the diet and only 30% is the genotype or heredity of animals. Thus, one of the basic conditions for further growth in animal productivity is a well-organized fodder supply.

One of the key challenges in agriculture intensification (and maintenance of the quality of feed) is the problem of increasing the production of plant protein, the most important source of which is pulse crops [2]. One of these crops is field beans [3], which are characterized by a vast productivity potential and the ability to accumulate protein in large quantities in seeds. Seeds of field beans contain 26-34% protein, 0.8-1.5% fat and 50-55% carbohydrates. Protein digestibility ranges from 50% to 86%. The high nutritional value of field beans is due to the presence of a significant amount of free amino acids, which are not part of the protein but are very easily digested by the body. Together with the essential amino acids, they make up 4-5% of the grain weight. The following was found in the seeds and vegetative organs of legumes: a large amount of carotene, vitamins A, B, B2, C, D, E, PP, etc., as well as all essential amino acids in the quantities necessary for a balanced diet: arginine – 8.05%, lysine – 2.2%, methionine – 1.58%, tyrosine – 3.15%, tryptophan – 1.3%, etc. [4]. Field beans are of interest as a fodder-grain crop and can play a large role in improving the fodder supply in Western Siberia [5], where they have been occasionally cultivated in recent years. Field beans are not only high in protein, but also one of the most productive leguminous crops [4]. A nine-year comparative study of leguminous crops in the sub-boreal forest in the Omsk region showed that, despite the fact that they were the most long-term crop, they provided the highest grain yield (2.88 t/ha) with high protein content (28.43%) [6]. In a farm test at “Sibiriya” LLC in the Golyshmanovsky District of the Tyumen Region, the yield of field beans over two years was 2.64 t/ha on average, and the protein content in dry matter was 30.2% (compared to 22.6% in green pea) [7].

Therefore, the study of the possibility of field beans cultivation, obtaining stable yields and quality, as well as

the use of grain in the feeding of dairy cows as part of animal feed is relevant.
The results of previous studies confirm the advisability of scientific work in this direction since the identified problems have not been completely resolved.

II. MATERIALS AND METHODS

The purpose of the research to study the effect of the sowing time and agrometeorological factors on the formation of grain yield of field beans in the Nonblack soil zone of Western Siberia and the effect of the feeding diet with field beans on the productivity of dairy cows.
The experiments were conducted on gray forest soils in the sub-boreal forest zone in the Omsk region in the year 2005-2014. The object of the study was the Siberian variety of field beans and the use of its grain in the diet of cattle as a part of compound feed created using the newly-developed experimental small-sized feed mill. The experiment was performed in quadruplicate; the allocation of the plots was randomized. Counts and observations were carried out according to the SSM (State System for Ensuring Uniform Measurement) technique. Zonal agricultural technology was used in the experiment. The preceding crops were spring grains. The tillage included: moldboard plowing to the depth of the arable layer after the preceding crops were harvested, early spring harrowing when the soil reached physical maturity and pre-sowing cultivation on the day of sowing. Sowing was performed starting from May 10-11 and then every five days using the ordinary drill sowing method with row spacing of 15 cm to a depth of 6-7 cm with a sowing rate of 0.7 million viable seeds per ha. Harvesting was performed using the direct combine method.
The weather conditions during the years of research were characterized by higher average daily air temperatures compared to the long-term average data. 2005 and 2012 were the warmest years, the average daily air temperature in May-September was 15.2℃ and 15.9℃, respectively; 2009 and 2010 were cool (13.8℃ and 13.7℃) and 2013 and 2014 were the coldest years with the same average daily temperature of 13.4℃. 2012 was the driest, with only 190.3 mm of precipitation; in 2005, 2006, 2010 and 2011, there was more rainfall – 200.4-237.5 mm; in 2008 and 2009, there was 259.1-274.1 mm of precipitation. 2007, 2013 and 2014 were the wettest, precipitation was higher than the average annual norm – from 304.3 to 353.2 mm, respectively. Different weather conditions during the years of research have affected the growth, development, maturation and yield of field beans.
The farm-scale experiment in studying the effect of the diet with field beans in compound feeds on the productivity of dairy cattle was carried out at the "Sibiriya" LLC in the Golyshmanovo District of the Tyumen Region. For this, two groups of cows were formed using the principle of analog groups, 120 animals in each [7].
To ensure a high degree of homogeneity of compound feed prepared in agricultural organizations, an experimental small-sized feed mill for the preparation and enrichment of compound feed concentrates with dry nutrient additives was developed and manufactured at the Department of Agronomy and Agricultural Engineering of the Tara Branch of the Omsk State Agrarian University. It can be used at livestock farms and complexes, as well as peasant and farm enterprises.

III. RESULTS

The beginning of the developmental phases in field beans was affected by the weather conditions of the years of research. For example, the shortest duration of the period "from sowing to seedlings" was 6-10 days and was observed at a higher average daily air temperature (14.9-22.9℃) and with lower precipitation (Table 1). This period was the longest at the lowest average daily temperature (8.4-14.5℃) and with higher precipitation. Similar dependencies were observed during the vegetation period of field beans. The shortest vegetation period was at an average daily air temperature of 19.1-19.9℃ and with a small amount of precipitation (69-83 mm) and it was longer (up to 100-122 days) in cold humid years with an average daily air temperature of 14.2-16.9℃ and with higher precipitation – 134-296 mm.

Table 1: Duration of periods depending on meteorological conditions.

Duration, days	Average daily air temperature, ℃	Effective heat sum, ℃	Total precipitation, mm
Sowing – seedlings			
6-10	14.9-22.9	117-159	0-33
11-15	9.9-15.0	86-165	6-51
16-20	8.4-14.5	67-226	10-65
Seedlings – ripening			
85-90	19.1-19.9	1,662-1,733	69-83
92-99	16.2-17.5	1,541-1,602	118-187
100-122	14.2-16.9	1,541-1,791	134-296

Thus, with an increase in the average daily air temperature, the duration of the period "from sowing to seedling", as well as the interphase and vegetation periods, decreased ($r = -0.54 \pm 0.12$ ... -0.91 ± 0.06) and with an increase in the amount of precipitation, they became longer ($r = 0.49 \pm 0.12$ ... 0.83 ± 0.10). Medium and strong correlation dependencies were noted.
Over the years of research, the vegetation period of field beans sown on May 10-20 was 104-105 days on average, ranging from 85-90 days in hot years to 114-122 days in rainy cool years.
The grain yield of field beans was affected by precipitation during the period "efflorescence – ripening" and during the vegetation period as a whole. Direct average correlations were noted: $r = 0.65 \pm 0.14$ and $r = 0.62 \pm 0.15$, respectively, that is, the yield increased with the increase in the amount of precipitation. Grain yield decreased with the increase in the average daily air temperature during the same periods, feed forward correlations were noted: $r = -0.51 \pm 0.16$ and $r = -0.55 \pm 0.16$, respectively.
The most favorable conditions for the formation of yield and ripening of field bean grain formed if the sowing was performed on May 10-15. In these conditions, the highest grain yields (2.81-3.00 t/ha on average) were

obtained over the years of research (Table 2). Yields were lower if the sowing was carried out later.

The average daily air temperature and the amount of precipitation also affected the protein content in the grain. The protein content in the grain increased with the increase in the average daily air temperature during the period “efflorescence – full ripeness” and during the whole vegetation period and decreased with the increase in the precipitation amount. A medium dependence on these factors was noted: the correlation with the average daily air temperature was r = 0.39 ± 0.21 and correlation with the total precipitation was r = -0.57 ± 0.19. Over the years of research, the highest protein content in the field bean grain was 27.7% and 28.3% on average when sown on May 10 and 15. It was lower if the sowing was carried out later (Table 2).

The study of the effect of agrometeorological factors on the growth and development of field beans at different sowing dates showed that in all years of research, field beans reached full ripeness when sown between May 10 and 20, except for May 20 in 2014. In 2007, 2009 and 2011, even the crops sown on May 25 ripened. In dry and hot 2012, beans sown even later (on May 30) also fully ripened. Thus, over ten years of research, field beans ripened in all years (in 100% of cases) if they were sown early on May 10-15. Field beans ripened in nine years if they were sown on May 20 (90.0%), in three years if they were sown on May 25 (30%) and in one year if they were sown on May 30 (10%).

Table 2: Bean yield and protein content depending on the sowing date.

Sowing date	Yield, t/ha	Protein content, %
May 10	2.81	27.7
May 15	3.00	28.3
May 20	2.49	27.6
May 25	1.93	27.0
May 30	1.30	26.2

The study of the effect of the diet with field beans on the productivity of dairy cattle showed that the inclusion of field beans in the compound feed for dairy cows made it possible to increase milk yield by 2.8 kg/day, as well as increase the protein content in milk by 0.17% and fat content by 0.2% [7]. At the same time, an increase in animal productivity provides an increase in milk production. Modern milk production should be highly efficient in market conditions and studies show that the profitability of milk production increases with the growth of animal productivity (Table 3).

Table 3: Dependence of financial results in dairy cattle breeding on the level of productivity.

Parameter	Milk yield per one forage-fed cow, kg				
	Lower than 3,000	3,001-4,000	4,001-5,000	5,001-6,000	More than 6,000
Profitability, %	16.4	18.3	27.7	34.9	36.4
Distributioncost, rub/kg	17.46	18.41	18.84	17.54	17.28
Saleprice, rub/kg	20.31	21.77	24.06	23.65	23.56

For example, a productivity level of less than 3,000 kg provides profitability of production at the level of 16.4% (Table 3). At the same time, profitability is 34.9% with a productivity of more than 5,000 kg, and an increase in productivity to more than 6,000 kg, increases profitability to 36.4% [8].

The ranging of agricultural organizations by milk herd productivity shows that only 13.5% of agricultural organizations in the region have animal productivity higher than 5,000 kg. Thus, the creation of a single effective system of animal husbandry and fodder production, which allows to fully realize the genetic potential and ensure high animal productivity, is an urgent need for the sustainable development of the regional animal husbandry system.

It should be noted that during the preparation of compound feeds and compound feed concentrates, it is very important not only to include all the necessary components in the required ratio but also to ensure a high degree of uniformity of the bulk feed mixture.

In most cases, the production of complete feeds in agricultural organizations is impossible due to the lack of a complete set of components; therefore, a rational solution is the preparation of compound feed concentrates from local raw materials [9].

Along with commercially available feed mills and bulk feed mixers (which in most cases do not provide sufficiently high quality of mixing of the prepared feed, or the mixing process is too long), it is necessary to use an experimental small-sized feed mill intended for the preparation and enrichment of compound feed concentrates with dry nutrient additives, which can be used at the livestock farms and complexes, as well as peasant and farm enterprises.

The unit consists of a multicomponent vibration dispenser (Fig. 1) and a vibration mixer (Fig. 2). The dispenser provides a uniform supply of components in a predetermined ratio and they are mixed in the mixer. Vibration effect causes the bulk feed to transfer to the state of “fluidization”, which increases its friability, eliminates arch formation and positively affects the accuracy of dosing and mixing quality.

The main components of the multicomponent vibration dispenser [10] (Fig. 1) are frame (1), electric motor (2), belt drive (3), eccentric drive (4), hopper (5), adjusting mechanism (8) and tray (12).

The eccentric drive of the tray consists of a shaft with an eccentric cam and a movable spring-loaded rod that performs axial vibrations.

Sliding bars with gear racks (9) move vertically in the guide grooves of the adjusting mechanism (Fig. 1). Clamps (10) connect the sliding bars to the adjustable shutters (11). The gear racks of the sliding bars are engaged with the gears (7), which are rotated by a manual drive (6).

The hopper (5) is divided into sections, the number of which is equal to the number of dispensed components. Partitions divide the tray (12) into the same number of sections.

The dispenser works as follows. Depending on the required ratio of the components, the opening of the outlet port (h) is set (Fig. 1) using the shutters (11), which are moved by the gear racks of the sliding bars (9) to the required height through the rotation of gears (7) by means of the rotation of the manual drive (6) and then fixed by the clamps (10). The sections of the hopper (5) are filled with bulk components to be mixed.

When the electric motor (2) is turned on, the rotation is transmitted through the belt drive (3) to the eccentric drive (4). The eccentric shaft starts to rotate; the eccentric drive converts the rotational movement of the shaft into vibratory movements of a spring-loaded rod pivotally connected to the tray (12). The tray makes vibratory movements, due to which the bulk components coming into it from the sections of the hopper are dispensed into the vibration mixer in a layer of a given height.

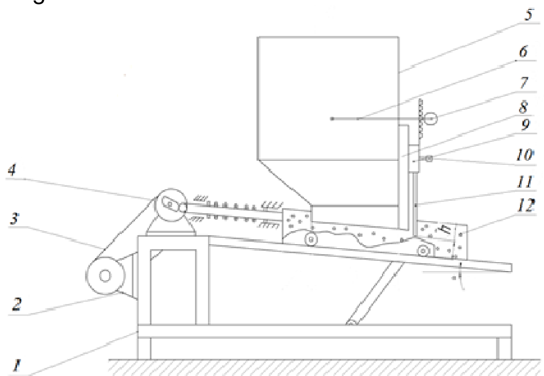

Fig. 1. Multi-component vibration dispenser: (1) frame (2) electric motor (3) belt drive (4) eccentric drive (5) hopper (6) manual gear drive (7) gears (8) adjusting mechanism (9) sliding bars with gear racks (10) clamps (11) shutters and (12) tray.

The main components of the vibration mixer [11-13] (Fig. 2) are the support frame, the swing frame, the vibratory chute with mixing elements, shock absorbers and the drive mechanism.

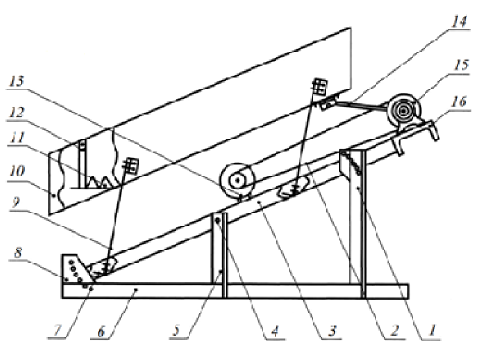

Fig. 2. Diagram of a vibration mixer for bulk feed: (1) rear pillar stands (2) V-belt transmission (3) longitudinal angles (4) rotary axis (5) middle pillar stands (6) lower longitudinal beams (7) jumpers (8) gussets (9) shock absorbers (10) vibratory chute (11) mixing elements (12) brackets (13) electric motor (14) pitman (15) eccentric mechanism (16) base plate.

The supporting frame (Fig. 2) includes lower longitudinal beams (6), rigidly connected to each other with cross-bars. Gussets (8), middle (5) and rear (1) pillar stands are fixed to the longitudinal beams.

The basis of the swing frame is the longitudinal angles (3); the base plate (16) of the eccentric mechanism is rigidly fixed to their ends; the shock absorbers (9) are bolted to the jumpers (7). The position of the swing frame can be changed, which allows setting the vibratory chute (10) at angles of 5°, 10°, 15°, 20°, 25° and 30° relative to the horizon. The vibratory chute rotates around axis (4).

The drive mechanism includes an electric motor (13), a V-belt transmission (2) and an eccentric mechanism (15). The vibration effects are transmitted from the eccentric mechanism to the chute through the pitman (14). The electric motor is mounted on the supporting plate of the swing frame and is powered by 220 V alternating current line supply through a rectifier installation. The vibration frequency of the chute can be controlled using a rheostat. Due to the design of the eccentric mechanism, it is possible to change the amplitude of vibrations of the chute within the established limits. The pitman is rigid, which ensures the constancy of the set amplitude of vibrations of the chute in the entire frequency range of the mixer.

The vibratory chute is mounted on shock absorbers. Special openings in the side plates of the vibratory chute and the lower shock absorbers mountings, the angle of vibration can be infinitely varied within the established limits. At the same time, the eccentric drive together with the driven pulley is moved along the guides in the base plate (16).

To intensify the mixing process, the vibratory chute is equipped with mixing elements with conical working surfaces [11]. One edge of each mixing element fits tightly with the bottom of the chute and the other two are attached to its sidewalls. The number and pitch of the mixing elements can be changed after loosening the clamps of the brackets (12).

The vibration mixer operates as follows. The components to be mixed are supplied in a predetermined ratio from the vibrating dispenser to the receiving part of the vibratory chute (10). Under vibration, they fall on the first mixing element and interact with conical surfaces, which results in different angles of reflection, different speeds and directions of movement. Due to the repeated intersection of the trajectories of moving particles, the mixing process intensifies.

After the feed mass passes the first mixing element, it falls freely on the bottom of the vibratory chute with subsequent movement to the second mixing element, where the processes of interaction with the conical surfaces repeat, etc. As a result of the movement of bulk components inside the vibratory chute, a homogeneous feed mixture is formed from them, which unloads from the discharge (lower) end of the vibratory chute.

Experimental studies of the operation of a small-sized feed mill were carried out. In the course of the research, a trial batch of mixed feed concentrates was prepared. The degree of homogeneity of the feed mixture was about 90%, which corresponds to zootechnical requirements [14].

IV. DISCUSSION

The results of the studies on the feasibility of cultivating fodder beans of the Siberian variety, the methods of their agricultural technology, as well as the use of their grain in the diet of dairy cows showed that the productivity of animals increased and, therefore, the profitability of milk production.

It has been proved by science and practice that the use of vibration effects on materials and the use of vibration machines are effective in many industries: the construction industry, medicine, the food industry, feed production, etc. Similar to vibration, oscillatory processes occur in grain cleaning machines [15]. Vibration even found its application for the theoretical analysis of automobile silencers [16, 17]. The use of vibrating machines, in particular dispensers and mixers, is a rational solution in the preparation of compound feed concentrates as well.

V. CONCLUSION

The results of ten years of research showed that sowing field beans on May 10-15 provided optimal conditions for the formation and ripening of grain crops. With this early sowing, field beans in the sub-boreal forest zone of Western Siberia ripened in all years (100% of cases), while field beans sown on May 20 ripened only in 90% of cases, beans sown on May 25 ripened only in 30% of cases and beans sown on May 30 ripened only in 10% of cases. The duration of the periods "sowing – seedlings" and "seedlings – ripening" depended on the sowing date and agrometeorological factors.

The grain yield and protein content in it also depended on the sowing period and the weather conditions. The grain yield of field beans increased with an increase in the amount of precipitation and the protein content increased with an increase in the average daily air temperature. Sowing on May 10-15 created the most favorable conditions for the formation of yield and protein accumulation in grain, and the highest yield (2.81-3.0 t/ha) and protein content in grain (27.7-28.3%) were obtained, which was confirmed by the results of industrial studies. Therefore, it is necessary to increase the planting acreage for field beans for use as fodder in the Nonblack soil zone of Western Siberia and, at the same time, to sow beans early on May 10-15.

To increase the productivity of dairy cows, it is necessary to include field beans grain in the feed (along with peas) and to increase the quality and uniformity of the prepared feeds using a vibration mixer for bulk feeds. At the same time, the profitability of milk production increases with the growth of animal productivity.

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