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The effects of NPK fertilization on hay production and some yield components of crested wheatgrass (*Agropyron cristatum*) in the dry steppe zone of Eastern Kazakhstan

Gulim O. Kamzina [a,*], Saule M. Seilgazina [a], Saule E. Suleimenova [b], Araily A. Zakieva [a], Aigul Zhamangarayeva [c]

[a] Shakarim State University of Semey, Kazakhstan
[b] Kazakh National Research Institute, Almaty, Kazakhstan
[c] Kazakh National Agrarian Research University, Almaty, Kazakhstan

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Author(s)

G.O. Kamzina *
S.M. Seilgazina
S.E. Suleimenova
A.A. Zakieva
A. Zhamangarayeva

* Corresponding author

Abstract

A three-year-long field experiment was conducted in a continuous grazing system with a variable stocking rate to evaluate effects of increasing NPK fertilization rates (Control- $N_0P_0K_0$, $N_{60}P_{40}K_{30}$, and $N_{80}P_{50}K_{40}$) in crested wheatgrass (*Agropyron cristatum*) on hay production, some yield components and crude protein concentration in the dry steppe zone of Eastern Kazakhstan. At harvesting, hay production (fresh and dry weight), seeding rate (SER), shrub diameter (SHD), height of generative shoots (HGS), length of root leaves (LRL), weight per bush (WEB), percentage of leaves and vegetative shoots (LVS) and crude protein concentration of crested wheatgrass (*Agropyron cristatum*) were determined. NPK fertilizer treatments increased hay production, SER, SHD, HGS, LRL, WEB, LVS and crude protein concentration. The results showed that crested wheatgrass at the $N_{80}P_{50}K_{40}$ treatments achieved a higher hay production and some yield components of crested wheatgrass (*Agropyron cristatum*) in the dry steppe zone of Eastern Kazakhstan than other NPK treatment and control.

Keywords: Crested wheatgrass, fertilization, hay production, crude protein concentration.

Introduction

Agriculture plays an essential role in Kazakhstan's economic, social and environmental development. Once considered the breadbasket of the Soviet Union, Kazakhstan still suffers from the effects of agricultural and environmental mismanagement during the Soviet era. Over a third of Kazakhstanis' livelihoods depend directly or indirectly on the country's extensive rangelands for food, fodder, fuel and medicinal plants. Widespread stockbreeding reflects the country's nomadic tradition, with around 75 percent of all agricultural land used for grazing. While sheep breeding dominates the sector, cattle, pig, horse and camel rearing are important sources of food and income (Privacyshield, 2022). In Kazakhstan livestock has always been a major focus in the agricultural sector and forage production is very important because the forage is the basic source of energy for the growth and maintenance of livestock and increase their products (Tazhibaeva et al., 2014). This attitude is clearly reflected on poor output and performance of animals resulting from poor quality of forages and the problems of over and under grazing. Overgrazing of natural pasture and improper conservation measures lead to reduction of rangelands. Most of the animals in Kazakhstan are greatly dependent on the natural vegetation as their major source of feed for maintenance and production. The possible solution to support the natural pastures is to establish and develop the pastures and encourage the utilization of agricultural by-products and residues that are produced in huge amounts for animals feeding in the Kazakhstan. The most important forage crop under dry steppe zone of Eastern Kazakhstan is crested

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wheatgrass and it is commonly used to natural pastures (Cheng and Nakamura, 2007). Crested wheatgrass is a long-life, perennial and cool season with extensive root systems forage plant. It is one of the most hardy and drought-tolerant plants among the grasses (Asay and Jensen, 1996). It grows itself in rangelands in dry steppe zone of Eastern Kazakhstan. It grows early in the spring and becomes ready for grazing and the animals eat it willingly. That's the reason why it is in short supply in our rangelands despite the fact that its homeland is Eastern Kazakhstan in Eurasia.

Forage production can be improved through fertilizer application, management of grazing, and control of weeds (McCarthy et al., 2016). The effects of fertilizers on forage production are examined through plot experiments, which attempt to simulate the real production systems (Delevatti et al., 2019). Most studies on grazing strategies aim to improve forage production and animal performance and are based on pasture height. And also, the nutrient contents of the forage have an important role in animal feeding. The factors influencing the nutritive value of forage are many, and the degree to which they are interrelated may vary considerably from one area to another. These factors may include, alone or in combination, plant type, climate, season, weather, soil type and fertility, soil moisture, leaf to stem ratio, and physiological and morphological characteristics, and may change depending on whether the plants are annuals perennials, grasses or legumes (Türk et al., 2009).

The importance of cultivated forage crops in dry steppe zone of Eastern Kazakhstan continues to increase. Each year more stockmen are turning to, or extending, established cultivated forage crops for their winter feed requirements. Unfortunately, many of the hay fields in dry steppe zone are composed of grasses only, notwithstanding recommendations to seed grass-legume mixtures. Grass alone becomes sod-bound quickly and resultant hay yields are low. This is attributable to an insufficient supply of available nutrient contents in an area where the climate is usually the main uncontrollable limiting factor. Thus, it seems important to learn as much as possible about the factors which can be controlled. Although fertilizer trials on cultivated grasses for hay in dry climates have been, and are being conducted, few results have been published. The aim of this research was to determine the effects of NPK fertilization on hay production and some yield components such as seeding rate, shrub diameter, height of generative shoots, length of root leaves, weight per bush and percentage of leaves and vegetative shoots of wheatgrass (*Agropyron cristatum*) plants in the dry steppe zone of Eastern Kazakhstan.

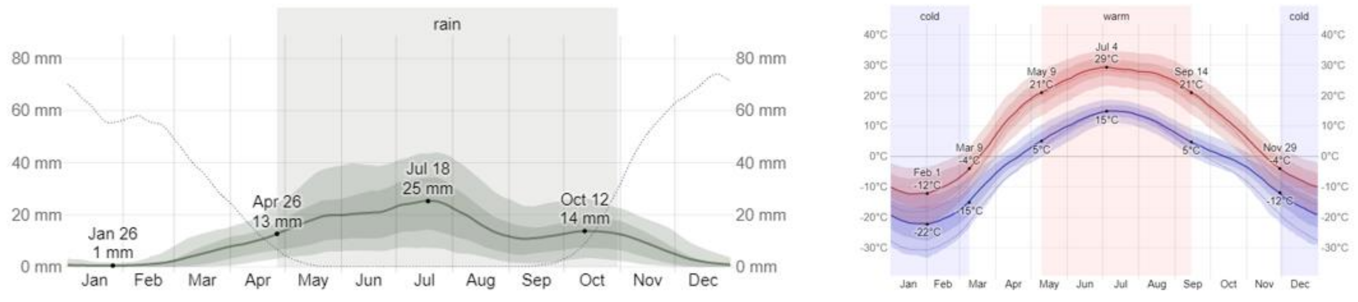
Material and Methods

Study Area

Kazakhstan is the world's ninth largest country with an area of 2.72 million km^2. It is mainly characterized by arid and semiarid conditions (Eisfelder et al., 2012). The main crop-producing areas of Kazakhstan are concentrated in the steppes in the northern parts of the country. This broad agroecological area consists of forest-steppe, steppe, dry steppe, semi-desert and desert. It is highly vulnerable to droughts (Broka et al., 2016). The steppe zone occupies 1.10 million km^2 or about 28% of Kazakhstan and is subdivided into 3 sub-zones: the moderately dry and warm zone of feather grass and various other grasses, the moderately dry and warm zone of tipchakovo and feather grass, and the dry, moderately hot wood and feather grass zone. The steppe zone has been transformed mostly by human activities. Large-scale ploughing of the land in the period of virgin land cultivation (1954-1960) led to the destruction of most of the main types of steppes. More than 38 million ha of land have been ploughed in the steppe zones. These include about 90% of the rich feather steppes and various grass valley steppes, 50-60% of the dry steppes in the plains, 30% of the low-hill steppes and 10-15 % of the small hill steppes. The remaining steppe lands in these sub-zones (stony, complex steppes on saline soils) have been significantly affected by overgrazing. The feather grass steppe has been invaded by typchakovyi (*Festuca valesiaca),* avstryisko feather grass (*Artemisia austriaca),* weeds and various grass communities (UN, 2000). East Kazakhstan region is located in the eastern part of Kazakhstan, on the border with Russia and China (Figure 1). The field experiment was located on peasant farm "Lana" of Beskaragai district, Earst Kazakhstan.

Figure 1. Study area

Experimental site has a dry steppe zone, with the mean annual temperature of 4°C and long-term average precipitation is 133.1 mm (Figure 2). The warm season lasts for 4.1 months, from May 9 to September 14, with an average daily high temperature above 21°C. The hottest month of the year in research area is July, with an average high of 29°C and low of 15°C. The cold season lasts for 3.4 months, from November 29 to March 9, with an average daily high temperature below -4°C. The coldest month of the year in research area is January, with an average low of -21°C and high of -12°C. A wet day is one with at least 1.00 millimeters of liquid or liquid-equivalent precipitation. The chance of wet days in research area varies throughout the year. The wetter season lasts 6.4 months, from May 6 to November 18, with a greater than 13% chance of a given day being a wet day. The month with the most wet days in research area is July, with an average of 5.7 days with at least 1.00 millimeters of precipitation. The drier season lasts 5.6 months, from November 18 to May 6. The month with the fewest wet days in research area is February, with an average of 1.9 days with at least 1.00 millimeters of precipitation. Among wet days, we distinguish between those that experience rain alone, snow alone, or a mixture of the two. Based on this categorization, the most common form of precipitation in research area changes throughout the year. Rain alone is the most common for 8.3 months, from March 13 to November 22. The month with the most days of rain alone in research area is July, with an average of 5.7 days. Snow alone is the most common for 3.6 months, from November 22 to March 13. The month with the most days of snow alone in research area is December, with an average of 2.2 days.



(A) (B)

Figure 2. Monthly average temperature (A) and distribution of precipitation (B) of the experimental area

Experimental Design

The experiments were carried out in 2018, 2019 and 2020 at the peasant farm "Lana" of Beskaragai district, East Kazakhstan. The experimental design was a randomized complete block with three treatments (Control-$N_0P_0K_0$, $N_{60}P_{40}K_{30}$, and $N_{80}P_{50}K_{40}$). These treatments were independent to each other. Plot size was 100 ha. The treatments were applied to the same plot areas for three successive years (2018, 2019, and 2020). For the fertilized treatment, fertilizers were applied with granule fertilizer spreader machine to the experimental plots at the end of May in the early growing period every year. The sources of fertilizers used were urea 46% N, double superphosphate 47% P_2O_5 and potassium chloride 60% K_2O. Soil samples were taken one times a year in spring (May) season between 2018 and 2020. After the soil samples were air dried and passed through a sieve with 2 mm size opening, some soil characteristics were determined as follows; total organic matter contents, soil reaction (pH), mineral-N, available phosphorus and available potassium as described by GOST 26213-2021, GOST 26423-85, GOST R 53219-2008 and GOST 26205-91.

Plant measurements and sampling

Measurements of three randomly selected quadrats (0.5 m × 0.5 m) were averaged in each plot with three replicates. Quadrats were established in the middle of each plot at least 10 m from the edge. All crested wheatgrass (*Agropyron cristatum*) plants were recorded, measured and clipped. Sampling and measurements were carried out following a consistent manner one times on 24 August. Plant height was measured on 10 plant individuals per species within each quadrat. After the harvest, the plants were trod and evaluated individually to determine the Forage fresh weights (FFW), Forage dry weights (FDW), Seeding rate (SER), Shrub diameter (SHD), Length of root leaves (LRL), Weight per bush (WEB), Percentage of leaves and vegetative shoots (LVS). After being harvested, the chickpeas was dried and milled and the crude protein content concentrations were determined.

For the crude protein content, the methodology proposed by Kjeldahl was used, finding the value of the total nitrogen (N) of the sample and later, converting to crude protein by the factor 6.25 - using three samples to cultivate in each of the tests, and each sample weighing 0.5 grams of dry and ground material (GOST 10846-91).

Results and Discussion

The soil pH was 7.77 (alkaline reaction), soil organic matter content was 2.59% (moderate), Easily hydrolysable nitrogen (NO_3-N+NH_4-N) was 39,2 mg kg^{-1}, available phosphorus was 26 mg kg^{-1} and available potassium was 740 mg kg^{-1} in experimental site.

Hay production (fresh and dry weight) crested wheatgrass (*Agropyron cristatum*) according to NPK fertilizer treatments are shown in Figure 3. The results showed that the effects NPK fertilization rates were significant in 2018, 2019 and 2020 years (Figure 3). Years were shown separately, because differences of years were significant all parameters of crested wheatgrass. The 4-year average yield increased with increasing levels of NPK, irrespective of the source of NPK. The highest yields were obtained in 2020 when the precipitation, particularly during the month of May and June, was high. The increases attributable to NPK treatments were good for crested wheatgrass. Generally, the highest hay production obtained by the N_{80} P_{50} K_{40} treatment in all years. The lowest yield was observed in the controls. Over the mean of the three years, fresh matter yield ranged from 1.46 to 1.57 ton ha^{-1} in the plots treated with NPK. Dry matter production in the control plot was 0.52 ton ha^{-1}, and NPK fertilizer treatments increased the dry matter production of the plots by about 28.9% (in $N_{60}P_{40}K_{30}$) and 40.4% (in $N_{80}P_{50}K_{40}$) in the present study. In various studies (Baenziger and Knowles, 1969; Lawrence and Knipfel, 1981; Jefferson and Cutforth, 2005), hay production of crested wheatgrass ranged from 1.28-10.19 ton ha^{-1} depending on growth environment, N fertilizer application, and cultivar. Walton (1983) described that fertilizers are normally used to increase forage yield and quality, but since plant tissue reflects the mineral constituents of the soil in which the plants are grown, quality is also greatly influenced. The herbage is especially responsive to the Ca, P, K, S, and N content of the soil.

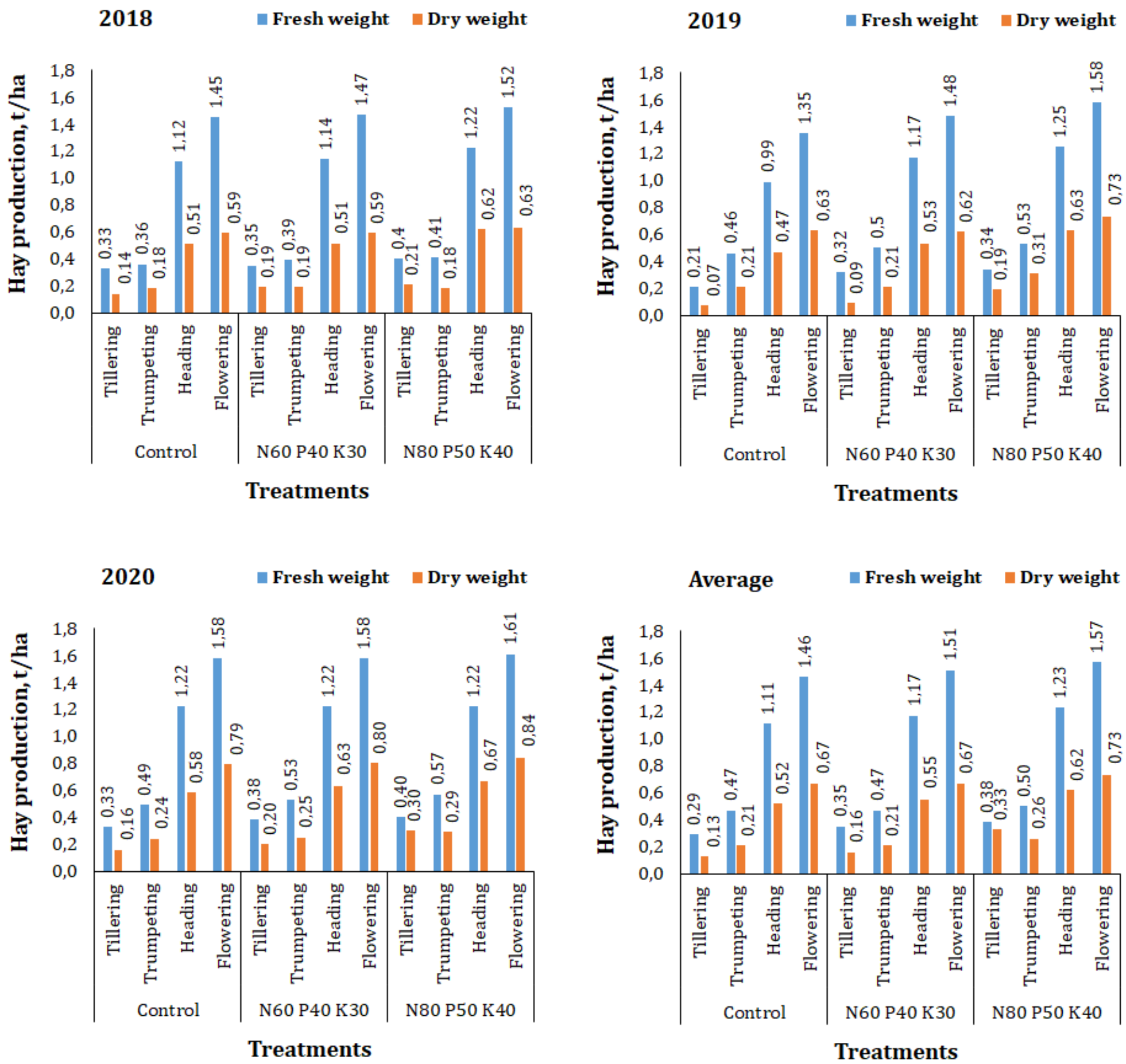


Figure 3. The effect of NPK fertilization rates on hay production (frest and dry weight) of crested wheatgrass (*Agropyron cristatum*) at different phenological stages during 2018, 2019 and 2020.

When species are grown in a pure stand, the effect of these minerals on the plant is direct. The uptake of nutrient was also affected by soil properties such as salinity and soil texture and forms of fertilizer treated (Irshad et al., 2002). Lauriault et al. (2002) reported that N is the most important fertilizer nutrient required for growing grasses. Increase in hay production due to N application is well documented by many authors (Power, 1986; Hall et al., 2003; Scarbrough et al., 2004). It was also found that the increase in NPK fertilizer level resulted in high hay production (fresh and dry forage yield) compared to the control. This is attributed to the fact that nitrogen increases the photosynthetic capacity of growing plants, which enhances growth to produce adequate dry matter. It is observed from the results of growth attributes, the fertilizer increased number of leaves per plant, plant fresh and dry weight, and leaf area index. Consequently higher yield could be expected at higher NPK fertilization level. This finding is in agreement with the finding of several research workers about the effect of nitrogen and phosphorus on yield of different forage grasses (Cowan et al., 1995; Buerkert et al., 2001).

The effect of NPK fertilization rates on Seeding rate (SER), Shrub diameter (SHD), Height of generative shoots (HGS), Length of root leaves (LRL), Weight per bush (WEB), Percentage of leaves and vegetative shoots (LVS) of crested wheatgrass (*Agropyron cristatum*) in 2018, 2019 and 2020 years is presented in Table 1. During all years there was significant difference in SER, SHD, HGS, LRL, WEB and LVS of crested wheatgrass between the different levels of NPK fertilization rate. The highest SHD, HGS, LRL, WEB and LVS were obtained at the higher NPK fertilization level ($N_{80}P_{50}K_{40}$) with highest width. On the contrary, the highest SER was obtained at the higher NPK fertilization level with the lowest width. The results revealed that the effect of NPK fertilization rates on SER, SHD, HGS, LRL, WEB and LVS were significant in all counting occasions during the experimental period. The increase in fertilizer level led to increase the SER, SHD, HGS, LRL, WEB and LVS. These results are in agreement with those reported by Kilcher (1958), Wilkinson and Langdale (1974), McCaughey and Simons (1996) and Türk et al. (2009) who stated that fertilization rates influence the growth attributes of grass.

For all three years, there was significant effect of NPK fertilizer treatments on crude protein concentration (Figure 4). In present study, increasing NPK treatments resulted in an increase in crude protein concentration. Generally, the highest crude protein concentration obtained by the $N_{80}P_{50}K_{40}$ treatment (9.45% in 2018, 10.04% in 2019 and 9.54% in 2020). The lowest crude protein concentration was observed in the controls. Crude protein is the amount of nitrogen from both protein and non-protein sources in the forage and is predictive of available protein. Crude protein concentration (%) of crested wheatgrass ranged from 14.4–22.8 at vegetative stage, 12.2-19.3 at boot stage, 11.9-12.4 at heading stage, 10.3-11.4 at anthesis , 6.5-10.2 5 at seed development stage, and 3.9-9.0 at seed maturity stage (Whitman et al., 1951; Glover et al., 2004; Biligetu et al., 2014).

In this research, increasing NPK fertilization led to slight increase in crude protein percentage. This result emphasized the fact that nitrogen plays a great role in synthesis of protein. Also phosphorus plays an important role in photosynthesis processes to produce protein and remobilization of sugar to starch. Similar results regarding the increased crude protein due to fertilizer application were obtained by several researchers. Brima and Abusuwar (2020) reported that nitrogen fertilization increased the crude protein of Rhodes grass.

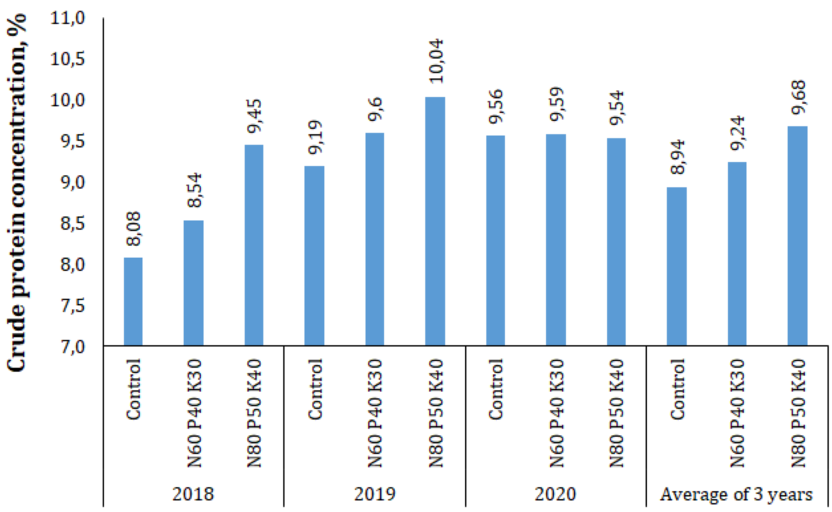


Figure 4. The effect of NPK fertilization rates on crude protein concentration of crested wheatgrass (*Agropyron cristatum*) during 2018, 2019 and 2020.

Table 1. The effect of NPK fertilization rates on Seeding rate (SHD), Shrub diameter (SHD), Height of generative shoots (HGS), Length of root leaves (LRL), Weight per bush (WEB), Percentage of leaves and vegetative shoots (LVS) of crested wheatgrass (*Agropyron cristatum*) during 2018, 2019 and 2020.

Year	Treatments	Width, cm	SER,mln/ha	SHD, cm	HGS, cm	LRL,cm	WEB, gr	LVS
2018	Control- $N_0P_0K_0$	10	3,0	2,5	45,5	13,0	3,8	89,3
		22	1,8	3,2	48,3	14,9	4,3	89,3
		38	0,8	3,5	48,0	14,9	4,5	88,3
		48	0,8	3,3	49,1	13,0	5,8	89,0
	$N_{60}P_{40}K_{30}$	13	3,5	3,5	50,0	14,8	4,4	99,2
		28	2,0	4,0	49,0	15,8	5,0	98,0
		42	1,2	4,2	51,3	14,8	5,5	98,3
		54	1,0	4,0	52,0	14,0	6,0	98,4
	$N_{80}P_{50}K_{40}$	15	4,0	3,9	50,4	15,1	4,4	99,8
		30	2,0	4,2	49,5	16,0	5,6	98,4
		45	1,3	4,4	51,6	15,5	5,8	98,8
		60	1,0	4,6	52,3	14,9	6,3	98,8
2019	Control- $N_0P_0K_0$	10	3,0	3,0	45,2	15,0	3,0	97,0
		20	1,0	3,2	43,0	15,0	5,8	98,2
		30	0,8	4,5	40,0	15,0	5,9	95,3
		40	0,5	4,3	40,3	16,3	6,0	93,5
	$N_{60}P_{40}K_{30}$	13	3,8	4,0	49,0	15,8	4,9	97,3
		27	1,9	4,1	52,3	15,8	5,8	98,0
		41	1,2	4,9	40,3	15,9	5,9	96,0
		54	0,7	4,8	50,0	16,7	6,9	94,8
	$N_{80}P_{50}K_{40}$	15	4,0	4,4	52,7	16,6	5,4	98,6
		30	2,0	4,7	56,7	17,3	6,1	98,1
		45	1,3	5,1	49,4	16,3	6,4	96,4
		60	1,0	4,8	52,3	17,1	7,1	95,7
2020	Control- $N_0P_0K_0$	11	3,5	11,0	54,8	20,1	19,3	90,1
		23	1,7	12,3	48,0	19,3	20,3	78,9
		43	1,2	11,7	49,3	17,3	25,7	79,3
		58	0,7	12,7	49,1	18,0	23,5	78,3
	$N_{60}P_{40}K_{30}$	15	4,0	12,0	55,1	22,0	24,1	90,1
		27	1,9	13,0	57,0	20,3	26,3	85,9
		43	1,2	12,1	55,0	23,0	28,3	85,3
		57	1,0	13,4	57,3	22,5	29,4	80,0
	$N_{80}P_{50}K_{40}$	15	4,0	12,1	55,4	22,2	24,5	90,6
		30	2,0	13,4	57,0	20,5	26,2	86,4
		45	1,3	12,6	55,4	23,2	28,5	85,4
		60	1,0	13,7	57,4	22,7	29,5	80,0
Average of 3 years	Control- $N_0P_0K_0$	10	3,2	5,5	48,5	16,0	8,7	92,1
		22	1,5	6,2	46,4	16,4	10,1	88,8
		37	0,9	6,6	45,8	15,7	12,0	87,6
		49	0,7	6,8	46,2	15,8	11,8	86,9
	$N_{60}P_{40}K_{30}$	14	3,8	6,5	51,4	17,5	11,1	95,5
		27	1,9	7,0	52,8	17,3	12,4	94,0
		42	1,2	7,1	48,9	17,9	13,2	93,2
		55	0,9	7,4	53,1	17,7	14,1	91,1
	$N_{80}P_{50}K_{40}$	15	4,0	6,8	52,8	18,0	11,4	96,3
		30	2,0	7,4	54,4	17,9	12,6	94,3
		45	1,3	7,4	52,1	18,3	13,6	93,5
		60	1,0	7,7	54,0	18,2	14,3	91,5

SER: Seeding rate, SHD: Shrub diameter, HGS: Height of generative shoots, LRL: Length of root leaves, WEB: Weight per bush, LVS: Percentage of leaves and vegetative shoots

Conclusion

Summarizing the results about the influence of NPK fertilizers on hay production and some yield components of crested wheatgrass (*Agropyron cristatum*) in the dry steppe zone of Eastern Kazakhstan, it is concluded that grass quality indices were mostly influenced by the rate of NPK fertilizer, by what the crude protein concentration in grass dry matter and its total yield per hectare increased considerably. The results of this study clearly indicate hay production, yield components and crude protein content was higher in $N_{80}P_{50}K_{40}$ treatment compared with $N_{60}P_{40}K_{30}$ treatment and control plots. At the end of the 3-year research conducted in dry steppe zone conditions of Eastern Kazakhstan, $N_{80}P_{50}K_{40}$ treatment is recommended for high hay production, yield components and crude protein concentration in crested wheatgrass.

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