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Full Length Research

Effect of crop variety and fertilizer application rates on productivity of winter wheat in saline soils

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Aridity of the climate, high summer and low winter temperatures, soil salinization and low nutrient contents in soil are among the main causes, which limit productivity of winter wheat in the northern zone of Karakalpakstan. Experiments to study adaptability of the different wheat varieties to the local climatic and soil conditions have been aimed at identifying the best performing, high-yield varieties. Among tested varieties, Polovchanka produced a highest grain yield in both trials under fertilizer application rates of $N_{120}P_{100}K_{60}$ and $N_{200}P_{120}K_{80}$. This variety has high values of the photometric leaf surface area (37-39.2 thousand m^2 ha^{-1}) and dry matter (9.26 t ha^{-1}). The yield of grain in the experimental site (1.01 t ha^{-1}) was substantially higher compared with that in the control site. The yield of wheat increases due to the higher number of productive crop stems per 1 m^2, grain weight per spike and higher weight of 1000 seeds. Compared with the traditionally applied fertilizer rates of $N_{120}P_{100}K_{60}$, application of $N_{200}P_{120}K_{80}$ contributed to the increase of all productivity indicators: Leaf surface area increased on the average by 8.3 thousand m^2 ha^{-1}. There was a high correlation (*R - 0.97)* between the increased fertilizer application rates and grain yield*.*

Keywords*:* Soil and climatic conditions, mineral fertilizers, productivity, crop leaf area, dry matter, Aral Sea region.

INTRODUCTION

Winter wheat (usually *Triticum aestivum*) according to Curtis et al.,(2002) are strains of wheat that are planted in the autumn to germinate and develop into young plants that remain in the vegetative phase during the winter and resume growth in early spring. Classification into spring or winter wheat is common and traditionally refers to the season during which the crop is grown in the Northern Hemisphere. For winter wheat, the physiological stage of heading is delayed until the plant experiences vernalization, a period of 30 to 60 days of cold winter temperatures (0° to 5 °C)

Winter wheat is the main grain crop in the Republic of Karakalpakstan and is planted in the area of 53 thousand ha. The winter wheat has longer growing period and so, produces higher yields compared with the spring wheat by better utilizing the solar energy, moisture in autumn and spring and soil nutrients.

The environmental and climatic conditions of Karakalpakstan are characterized by aridity of the climate, low precipitation, limited freshwater for crop irrigation. The organic matter and available plant nutrients in soils of the region are low. Excessive contents of mineral salts in the soils suppress the crop growth and development, reducing the quantity and quality of yield of the cereal crops (Sultanova, 2010). As a result, productivity and grain quality of the winter wheat are reduced substantially.

Correct choice of the crop varieties, sustainable to adverse climatic and soil conditions is of high importance in increasing the yields and grain quality of winter wheat (Il'ina, 1984; Balashov and Levkin, 2007; Maslenko, 2007; Koleda and Duduk, 2010; Kononenko et al, 2010; Novikov and Zharikhina, 2013; Grabovets and Fomenko, 2013; Workineh et al, 2014). High and sustainable wheat yields of good quality can only be obtained by cultivating the varieties, which are well-adapted to the local conditions. The purpose of this paper is to study productivity of promising wheat varieties and their grain quality under traditional and experimental fertilizer application rates.

The growth, development and productivity characteristics of various winter wheat varieties were monitored in the soil and climatic conditions of the Aral region for selection of the most optimal variety for cultivation in these conditions.

MATERIALS AND METHODS

Environmental characteristics of the region

The Aral Sea was an endorheic lake lying between Kazakhstan (Aktobe and Kyzylorda Regions) in the north and Uzbekistan. The Aral Sea region is characterized by the sharply continental climate. Remoteness from seas, aridity of the climate, high temperature in summer, long lasting low air humidity are the distinctive features of the region. Precipitation in the range of 60-100 mm yr^{-1} takes place mainly in winter and spring. Average annual temperature fluctuates sharply from -30ºC in winter to +45ºC and higher in summer seasons.

The soils of the Aral region are meadow-alluvial, with a low intensity of the soil-forming processes, low organic matter contents and are subject to salinization processes.

During the years of observations, the climatic conditions of the winter period were adverse, with low precipitation and strong winds, and with fluctuations of the air temperature from >0 to -30°C.

Research site

The experiments have been carried out in the fields of the "Seyit" farm in the Nukus district. The samples were analyzed in the laboratory of the Nukus branch of the Tashkent State University in 2013-2014. The soils of the research site are meadow-alluvial, sandy loamy. The nitrogen contents in the soil range between 1 – 1.7 mg per 100 g. of soil.

In spring, plants suffer from adverse conditions due upward migration and accumulation of salts into the upper soil horizons and especially within the upper soil root zone. Growth and development of plants, their density per area decrease; the productivity of the wheat grain is very low compared with the grain yields in the non-saline areas (Sultanova, 2010).

Four winter wheat varieties of the intensive type were selected for experimentation. The selected varieties are tolerant to drought, good adaptation to cultivation in unfavorable soil and climatic conditions. The tested varieties are Chillaki (control experiment, local breed variety), Polovchanka, Kroshka and Yuna.

As the soils of the research site are poor in nutrients, two mineral fertilizer rates, $N_{120}P_{100}K_{60}$ and $N_{200}P_{120}K_{80}$ were applied to study the reaction of the selected varieties on these rates. The former fertilizer application rate ($N_{120}P_{100}K_{60}$) is traditionally used in wheat cultivation in the region and therefore, is chosen as control.

Research methodology

Field and laboratory studies were conducted according to the generally accepted practices of the field experiments and breeding of the agricultural crops. The experimental plot size were 60 m^2 with control size of 50 m^2; with four repetitions. The experimental and control plots were randomized. Statistical analyses of the experimental data were done according to Dospekhov (1985).

Agro-technology of the field experiments

Following harvest of the preceding crop (maize as silage), soil disking was conducted. After the emergence of weeds, the soil was plowed to a depth of 27-30 cm. Planting was carried out during September, 20 to October, 10. The following volumes of the phosphorous and potassium fertilizers have been applied into the soil plowing: 50 % prior to planting, 25 % during early spring before the spring tillering and the last 25 % in early March in the phase of stem elongation. The wheat was sown at the rate of 6 million seeds per ha into a depth of 3-4 cm. Wheat was harvested during the full maturity phase.

RESULTS

Wheat germination and vernalization are important in creating the optimal plant density. The seed germination in all experiments was approximately at the same level ranging between 72-74 % from total applied seeds (Table 1).

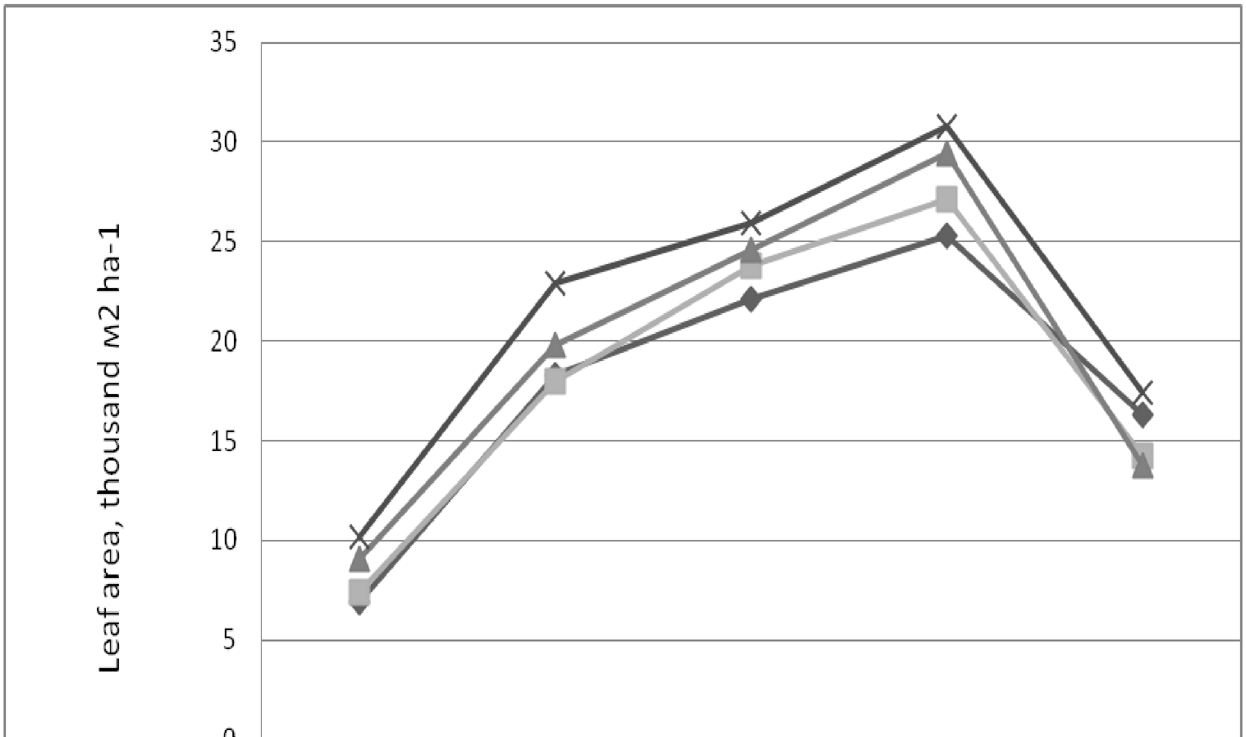
Among the studied varieties, a higher survival rate to vernalization was observed in two varieties: Yuna (77 % from fully emerged plants) and Chillaki (80 %). Application of mineral fertilizer rate of $N_{200}P_{120}K_{80}$ contributed to a well development of plants and 3.8% higher survivability by the time of harvest compared with the traditional application volumes $N_{120}P_{100}K_{60}$. The varieties Yuna and Kroshka manifested the highest survival rates by the harvest time in the range of 82-83%.

The leaf surface area of winter wheat plants is an important characteristic of the photosynthesis productivity in different conditions. The leaf area reached maximum values of 33.8 - 39.2 thousand m^2 ha^{-1} in the heading phase and then decreased in all trials towards maturation and dying off (Figure 1, 2).

The varieties Polovchanka and Yuna manifested the

Table 1: Germination, vernalization and plant survivability of winter wheat by varieties, % (on average for 2 years)

Varieties	Germination	Vernalization		Survivability of plants by a harvest period	
		Under $N_{120}P_{100}K_{60}$	Under $N_{200}P_{120}K_{80}$	Under $N_{120}P_{100}K_{60}$	Under $N_{200}P_{120}K_{80}$
Chillaki	73	75	80	78	81
Kroshka	72	77	74	79	82
Yuna	74	76	77	79	83
Polovchanka	74	74	75	77	82



	Tillering	Stem elongation	Stem elongation	Heading	Milking maturity
Chillaki	6.9	18.3	22.1	25.3	16.3
Kroshka	7.4	18	23.8	27.1	14.2
Yuna	9.1	19.8	24.6	29.4	13.8
Polovchanka	10.2	22.9	25.9	30.8	17.4

Figure 1: Dynamics of leaf surface area formation by studied winter wheat varieties under fertilizer application rate of $N_{120}P_{100}K_{60}$

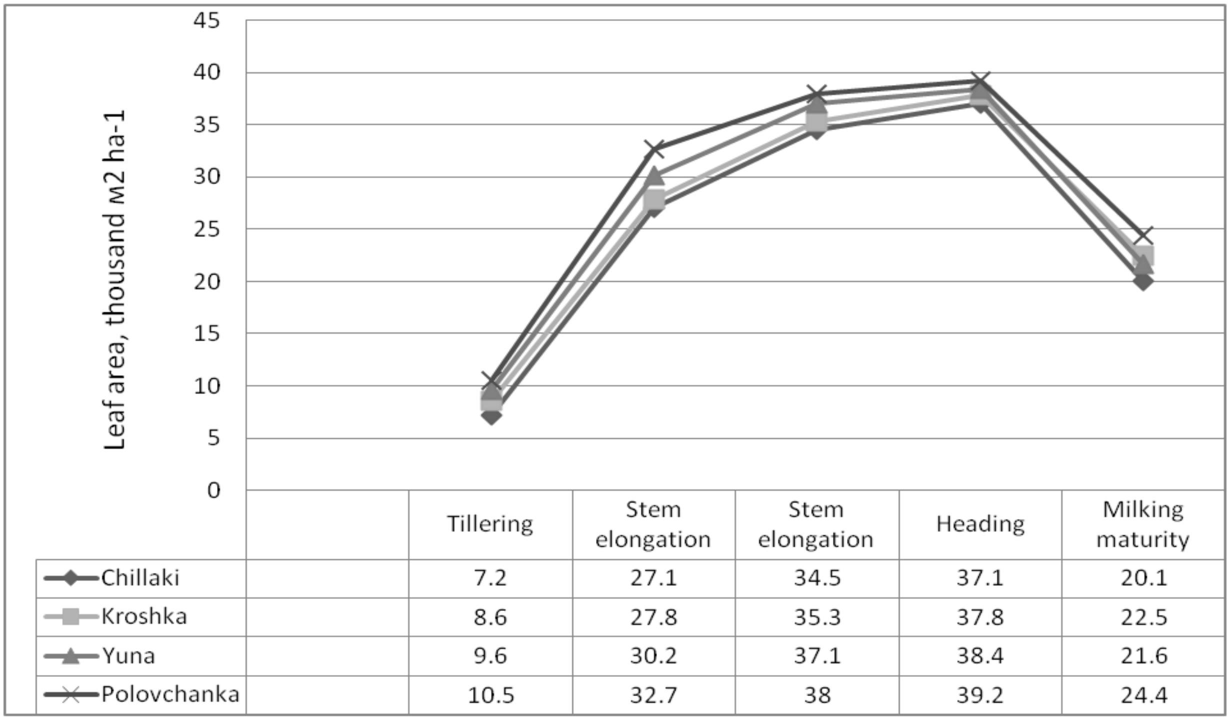


Figure 2: Dynamics of leaf surface area formation by studied winter wheat varieties under fertilizer application rate of $N_{200}P_{120}K_{80}$

Table 2: Dynamics of dry matter accumulation in wheat by varieties under the various mineral fertilizer application volumes, t ha^{-1}

Variety	Fertilizer application rate	The accumulation of dry substances, t/ha					
		Tillering	Tube elongation	Heading	Flowering	Milking maturity	Complete maturity
Chillaki	$N_{120}P_{100}K_{60}$	0.61	0.83	4.22	6.27	6.84	7.36
Kroshka		0.77	1.62	4.45	6.43	7.06	7.51
Yuna		0.73	1.58	4.70	6.61	7.37	7.68
Polovchanka		0.78	1.93	4.94	7.04	7.68	7.95
Chillaki	$N_{200}P_{120}K_{80}$	0.70	2.01	5.02	7.04	7.52	7.74
Kroshka		0.83	2.25	5.32	7.46	7.89	8.22
Yuna		0.89	2.16	5.64	7.88	8.33	8.58
Polovchanka		1.01	2.44	6.03	8.50	9.10	9.26

highest leaf surface areas of 39.2 and 38.4 m^2 ha^{-1}, respectively, in their heading phase. After the flowering phase the leaf surface areas decreased due to the natural process of grain maturation and plant senescence.

According to Nevolina et al. (2013), application of the mineral fertilizers has a considerable influence on the photosynthetic plant activities and grain yield of winter crops. Application of $N_{200}P_{120}K_{80}$ has contributed to an increase in the leaf surface area on average by 8.3 thousand m^2 ha^{-1} and the formation of the high-capacity photosynthetic potential of crops compared with the traditional rate of $N_{120}P_{100}K_{60}$. Among other varieties, Polovchanka and Kroshka had high photometric values.

Accumulation of dry matter has an effect on the yield of winter wheat. The greatest dry matter was observed during the intensive plant growth phase of the stem elongation – flowering (Table 2). Application of the increased rates of mineral fertilizers contributed to the increase of plant dry matter on average by 0.83 t ha^{-1}. Compared with the control trial, the dry matter accumulation of the Polovchanka variety was 1.06 t ha^{-1}, of the Kroshka variety 3.15 t ha^{-1} and of the Yuna 5.8 t ha^{-1} higher.

Yield of grain is a final result of the photosynthetic plant activities (Table 3, 4). The main components determining the productivity of winter wheat in the Republic of Karakalpakstan are the number of

Table 3: Grain yield of the winter wheat varieties and yield structure

Variety	Fertilizer application rates	Yield, t ha^{-1}	Increase of yield of the control variety, t ha^{-1}	Increase of yield of the experimental varieties compared to control, t ha^{-1}	Increase of yield due to increased fertilizer application rates, t ha^{-1}	Increase of yield due to increased fertilizer application rates, %	Number of productive stems per 1 m^2	Grain weight of a spike, g	Weight of 1000 grains, g
Chillaki	$N_{120}P_{100}K_{60}$	3.17	-	-			461	0.70	38.8
Kroshka		3.32	0.15	4.7			453	0.73	34.3
Yuna		3.40	0.23	7.2			492	0.78	34.8
Polovchanka		3.61	0.44	11.3			518	0.83	36.2
Chillaki	$N_{200}P_{120}K_{80}$	3.83	-	-	0.66	20.8	563	0.82	36.6
Kroshka		4.06	0.23	6.0	0.74	22.2	586	0.90	37.5
Yuna		4.18	0.35	9.1	0.78	22.9	627	0.94	38.4
Polovchanka		4.62	0.79	20.6	1.01	30	664	1.10	41.5

Table 4: Effect of fertilizer application rates and various varieties on yields of winter wheat, t ha^{-1}

Fertilizer application rate	Variety				Average by an A factor, STD_{05}=0.14
	Chillaki	Kroshka	Yuna	Polovchanka	
$N_{120}P_{100}K_{60}$	3.17	3.32	3.4	3.61	3.38
$N_{200}P_{120}K_{80}$	3.83	4.06	4.18	4.62	4.17
Average by a B factor, STD_{05}=0.108	3.5	3.79	3.89	4.11	3.77
STD_{05}=0.26 for comparison of averaged values					

productive stems per unit area and the size and productivity of wheat spikes. Increased mineral fertilizer rates resulted in the yield increase of 0.66 t ha^{-1} (20 %, Chillaki variety) and 1.01 t ha^{-1} (27 %, Polovchanka variety). Increasing the nitrogen application rates caused a proportional increase in the grain yields. There was a high correlation (*r 0.97)* between the increased rates of the fertilizer application and grain yields.

The additional increase of the grain yield from 0.15 to 0.44 t ha^{-1} (5 – 14 %) was observed due to the use of the studied varieties under the fertilizer application rates of $N_{120}P_{100}K_{60}$. However, increased application rates of $N_{200}P_{120}K_{80}$ resulted in even higher yields of 0.23 to 0.78 t ha^{-1} (6 – 20 %) compared with the control (Chillaki variety).

The Chillaki variety has better tolerance to drought and similar grain productivity as such varieties as Yuna and Kroshka. However, widespread use of this variety is restricted by seed fall and related yield losses during ripening, exacerbated by the high air dryness in this period.

The Polovchanka variety is better adapted to the climatic and soil conditions of the region, and ensures high grain yields (4.62 t ha^{-1}) compared with the other varieties. Analysis of the yield structure (Table 4) showed that the grain yield has formed due to a higher number of productive spikes and grain weight from a spike.

CONCLUSIONS

The use of increased nitrogen application rates of $N_{200}P_{120}K_{80}$ has contributed to a better growth and development of the winter wheat plants, a greater leaf surface area, longer period of their photosynthesis activities and increased dry matter compared with the traditionally applied rates of $N_{120}P_{100}K_{60}$.

Increased application rates of the mineral fertilizers positively impact crop productivity (*r 0.97).* Therefore, the application of $N_{200}P_{120}K_{80}$ is more appropriate and is compensated by an additional grain yield by 0.66 – 1.01 t ha^{-1} as it contributes to a better development and tolerance of the plants to such stresses as soil salinization and climate aridity.

The yield of the Polovchanka variety was 0.3-0.62 t ha^{-1} higher compared to the other varieties due to higher vernalization rates, heat- and salt-tolerance. Therefore, this variety can be recommended for cultivation for grain production.

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