Turk J Agric For
29 (2005) 143-150

Role of Wheat in Diversified Cropping Systems in Dryland Agriculture of Central Asia

Mekhlis SULEIMENOV[1,*], Kanat AKHMETOV[2], Zheksembay KASKARBAYEV[2], Aitkalym KIREYEV[3], Lyudmila MARTYNOVA[4], Rakhim MEDEUBAYEV[5]

[1]ICARDA-CAC, Tashkent, Uzbekistan

[2]Scientific Production Center of Grain farming, Shortandy, Akmola, Kazakhstan

[3]Scientific Production Center of Cropping Systems, Almalybak, Almaty, Kazakhstan

[4]Research Institute of Cropping Systems, Bishkek, Kyrgyzstan

[5]Krasniy Vodopad breeding station, Shymkent, Kazakhstan

Received: 24.12.2003

Abstract: Wheat is major crop in dryland agriculture of Central Asia. In most cases both spring wheat and winter wheat are grown in rotation with summer fallow. Studies were conducted in order to identify alternative crops which possibly could replace part of summer fallow and part of wheat area. Summer fallow was found inefficient practice for soil moisture accumulation in semiarid steppes of northern and southern Kazakhstan as well as in Kyrgyzstan. Many alternative crops were identified in all zones of dryland farming providing better incomes to farmers than wheat. Most important are food legumes as field pea, chickpea, lentil, oilseeds as safflower and mustard, small grains as buckwheat and millet . Food legumes and alfalfa are also very important for sustainability of production systems.

Key Words: Dryland, crop rotation, crop diversification, summer fallow

Introduction

Wheat is major crop in dryland agriculture and one of two major crops in irrigated agriculture of Central Asia. Dryland agriculture is major production system in Kazakhstan, while in the rest of the region agriculture is predominantly irrigated. In the northern Kazakhstan spring wheat is major crop grown traditionally in summer fallow-small grains programs, in the rest of the region winter wheat is cultivated in fallow based rotations in dryland and in cotton-wheat programs under irrigation. During a transition period which started right after collapse of the Soviet Union in 1991 and establishment of newly independent states, role of wheat has changed dramatically in all countries of Central Asia. In most countries of the region role of wheat increased whereas in Kazakhstan an area under wheat reduced remarkably. Studies in the dryland areas of Central Asia were conducted to find out possibilities to reduce area under summer fallow or to eliminate it, because it remains a major area subjected to soil erosion. Also several crops were tested as possible alternatives to spring or winter wheat for crop diversification to increase sustainability of production systems.

Materials and Methods

The Shortandy site in northern Kazakhstan is located in semiarid steppe on chernozem soil heavy clay loam with the humus content 3.5%. Annual average precipitation is 350 mm with maximum in July and one third of precipitation falls as snow. Annual average air temperature is 1.2 ^{0}C. Studies on crop rotations were conducted during 2000-2002. The widespread crop rotation "fallow-wheat-wheat-barley" was taken as control. In two more rotations the summer fallow was replaced by oats or dry pea. The establishment of crop

* Correspondence to: M.Suleimenov@icarda.org.uz

rotations started earlier so that during the study years it was possible to make an assessment of all crops included into the three crop rotations. Phosphorus fertilizer was applied at the 60 kg of P/ha once in four years during fallow period or before planting substitute crop of fallow.

The experiments in rain-fed conditions of southeastern Kazakhstan, Almalybak were conducted on light chestnut soils heavy clay loam with humus content 2.4%. Annual average precipitation rate is around 350 mm, average annual air temperature is 7.5 ^{0}C. Studies on crop rotations were conducted during 2001-2002 in arid and semiarid conditions. In the semiarid zone nine crops were tested sown on stubble land. The average annual precipitation rate in arid zone is 220 mm. In the arid zone a comparative study of eight crops was conducted during two years on fallow and one year on stubble land.

The Krasniy Vodopad site in southern Kazakhstan is located in semi-arid steppe with an average annual precipitation 420 mm, distributed with maximum in winter-early spring season. The climate is continental, but much warmer than in the southeast with an average annual temperature 14.1 ^{0}C. Major crop is winter wheat usually sown on fallow. In crop rotation experiment, winter wheat sown during two years after summer fallow and after alfalfa was compared to wheat sown after chickpea and to continuous wheat.

Zhany pahta site in Kyrgyzstan is located in semiarid steppe. The annual average precipitation is 300 mm, average annual temperature is 8.5^{0}C. Crop rotation studies included growing winter wheat after fallow as compared to growing after field pea and safflower. Crop rotations were studied with fertilizers at the rates 60 kg/ha of P before fallow or crops replacing fallow, 45 kg of N was applied to wheat. Two more treatments of improved fallow were studied: with manure applied at the rate of 30 t/ha and straw of the harvested crop.

Results

Studies on crop rotations in dryland conditions were conducted in Shortandy, northern Kazakhstan to compare four-year rotations. The standard crop rotation was a generally adopted rotation of summer fallow with three year consecutive small grains: "summer fallow-wheat-wheat-barley". This was compared to continuous cropping when the summer fallow was replaced by oats or field pea. The yield data was collected during three years: 2000, 2001 and 2002. All three years were relatively favorable as far as precipitation rate is concerned. The year 2000 was characterized by very rainy period prior to sowing and before tillering of small grains and very dry period between the tillering and heading of wheat. The year 2001 on the contrary was featured with dry and cool weather during the first part of the vegetation of spring wheat and with very rainy season from the jointing stage till the grain filling causing rather intensive development of plant diseases. During the vegetation period in 2002 rainfalls were well above average accompanied with warm temperatures leading to higher than normal occurrence of plant diseases. On average for three years and during each of three years the grain yield was affected by placement of wheat after fallow or other preceding crops (Table 1).

Table 1. Grain yield of wheat, barley, oats and dry pea in three crop rotations in northern Kazakhstan, average for 2000-2002.

Crop sequence	Crop rotation*		
	F-W-W-B	O-W-W-B	P-W-W-B
	Grain yield, t ha^{-1}		
1. Fallow (oats, pea)	0	2.67	1.60
2. Wheat	2.07	1.72	1.64
3. Wheat	1.71	1.48	1.50
4. Barley	2.62	2.84	2.24
	Grain yield from total rotation area, t ha^{-1}		
	1.59	2.07	1.75

* F: Follow; O: Oat; W: Wheat; B: Barley

The spring wheat grain yield was the highest on summer fallow with an advantage of 20-25% as compared with the yield of wheat sown after oats and dry pea respectively. The advantage of summer fallow against stubble land in available moisture storage by the time of sowing spring wheat during two years amounted to 20-30 mm in 1 meter layer, whereas in 2001 it was even 20 mm higher on stubble land. The yield of wheat when sown after wheat as compared to wheat sown after oats or dry pea had no significant difference.

The yield of barley was higher than that of wheat by 65%. It was higher in the rotation with oats and fallow, but rather low in the rotation with dry pea, which indicates that in dryland conditions of northern Kazakhstan food legumes didn't play a positive role as predecessor of small grains. Besides, one of negative factors associated with the dry pea was weed infestation, which was remarkably higher as compared to the rotation of small grains with the summer fallow or oats. The average weed density in the rotation with dry pea was substantially higher especially of grass weeds, of which wild oats was the major representative. The dry weight of weeds on average during three years was 9.9, 10.1 and 19.2 g/m^2 in rotations with fallow, oats and dry pea respectively. It is important to emphasize that dry pea stand wasn't treated with chemicals, whilst small grains were sprayed by 2,4-D herbicide.

Oats replacing fallow and leading to the continuous cropping proved to be as high yielding as barley. Dry pea gave comparable grain yields to spring wheat. Thus, including of oats and dry pea as replacement of summer fallow considerably increased the grain yield from total area including summer fallow.

In all three years the grain yield from the total area including fallow land was the lowest from the rotation "fallow-wheat-wheat-barley". The replacement of fallow with oats increased the grain production by 30% on average with little difference between three years. The replacement of fallow with dry pea also increased the total production by 10%. Thus, both treatments with continuous cropping instead of rotation of small grains with summer fallow provided increase of grain production from total cropland. Most important is the fact that reduction or removal of summer fallow from cropping practices will contribute significantly to conservation agriculture, because the fallow practice is most dangerous provoking soil erosion.

The crop rotation with dry pea replacing fallow produced more grain from the total cropland area. At the same time reduction of area under summer fallow solved an issue of soil erosion, because fallow is the only farming practice causing soil erosion and losses of organic matter under soil conservation tillage.

Studies in the northern Kazakhstan have shown real possibilities for crop diversification. When sown on summer fallow bread wheat provided the highest grain yield but proved to be least economical under current market prices (Table 2).

Bread wheat is the most widespread crop in northern Kazakhstan. It provided the best grain yield but proved to be the least economical because of current grain prices affected by world market and surplus of grain production in Kazakhstan during three years in a row and good grain production in the rest of Central Asia and in Russia in 2002.

Table 2. Comparative yields and profit margins of different crops in northern Kazakhstan (average for 2000-2002).

Crop ranking	Grain yield, t ha^{-1}	Crop ranking	Profit margin, %
1. Bread wheat	2.45	1. Lentil	176
2. Durum wheat	2.40	2. Dry pea	170
3. Field pea	2.02	3. Buckwheat	103
4. Millet	1.67	4. Millet	78
5. Buckwheat	1.47	5. Durum wheat	61
6. Lentil	1.43	6. Mustard	46
7. Mustard	1.14	7. Bread wheat	22

Durum wheat provided comparable yield to bread wheat but was found more profitable thanks to better price.

Food legumes did well as far as economics is concerned. The best in terms of yield was field pea with grain yield two third of bread wheat. Lentil was a little lower yielding, but the profit margin was obtained the same: 170% and 176 % respectively. Chickpea failed in one out of three years, because the Russian variety was used in experiment, which proved to be susceptible to Ascochyta blight. New chickpea varieties from ICARDA resistant to Ascochyta blight were identified, but they are not released yet. In two years when chickpea didn't fail, its yield was comparative to field pea and higher than that of lentil.

Millet (proso) on average gave significantly lower grain yields than bread wheat. It didn't use favourable weather with good rainfalls, but looked better in relatively dry year. But even at lower grain yields it proved to be much more profitable than bread wheat with the profit margin as high as 78%. Buckwheat produced grain yield on average 60% of bread wheat, which was enough to have better profit margin (103%). Buckwheat was competing with wheat better under favourable weather conditions. Oilseeds failed mostly because of serious damage by insect pests, although treatments were done to control them. As one can see all alternative crops were found more profitable than bread wheat, which happened because of low wheat prices.

Studies in southeastern Kazakhstan were conducted in the areas with arid and semi-arid rainfed conditions. First thing, which is obvious for the arid dryland area, there was no other successful crop growing practice except alternate summer fallow and crop (Table 3).

Barley is suitable crop for planting in spring insuring grain yields equal to winter wheat. Oats provided grain yield less stable than barley: higher than barley in wet year and lower in dry year. Food legumes were low yielding (half yield of winter wheat), but they may compete, taking into consideration that market prices exceed price of wheat three-four times. Safflower is another alternative oilseed crop with good potential. The yields of safflower were about 67% of wheat. In 2002 wheat price went down while safflower price went up making this crop very promising for farmers. Many conclusions made in arid area have been repeated in the semi-arid area with more reliable rainfalls, but growing on stubble land was feasible.

During three years at the Krasniy Vodopad station, in addition to recommended growing winter wheat during two years after summer fallow and two years after alfalfa, it was winter wheat sown after chickpea. Out of three years 2000 and 2001 were typically dry, and 2002 was rainy (60% more rainfall than rate). The data obtained very distinctly showed, that chickpea is very good alternative to produce food legume and improve grain yield of wheat (Table 4).

Table 3. Comparative crop yields on fallow and stubble in arid rainfed area in southeastern Kazakhstan.

Crop	On fallow			On stubble
	2001	2002	Mean	2001
	Grain yield, t ha^{-1}			
Winter wheat	0.63	1.79	1.21	0.33
Spring wheat	0.40	1.00	0.70	0.19
Spring barley	0.68	2.27	1.48	0.22
Oats	0.38	2.40	1.39	0.11
Millet (proso)	0.37	1.39	0.88	0.09
Lentil	0.29	0.89	0.59	0.08
Chickpea	0.32	0.99	0.65	0.13
Safflower	0.77	0.85	0.81	0.43
LSD_{05} t ha^{-1}	0.11	0.35		0.06

Table 4. Wheat grain yield as affected by crop sequence in southern Kazakhstan.

Preceding crop or fallow	Year			Mean
	2000	2001	2002	
	Grain yield, t ha^{-1}			
Continuous wheat	0.70	0.96	1.78	1.15
Summer fallow	1.62	1.42	3.01	2.02
Wheat after fallow	0.93	1.10	2.22	1.42
Alfalfa	1.47	1.32	2.86	1.88
Wheat after alfalfa	1.27	1.40	2.17	1.61
Chickpea	1.53	1.38	2.74	1.88

Continuous winter wheat produced in wet year double crop, but on average it was rather low. In both dry and favorable years summer fallow provided very reliable grain yield, on average increasing wheat yield by 76%. But in the second year after summer fallow the wheat yield fell down dramatically, and made only 23% advantage to continuous wheat. Alfalfa grown during four years proved to be very good preceding crop for wheat, providing 63% higher wheat yield compared to continuous cropping and 93% of wheat on summer fallow. Remarkably, the second wheat after alfalfa gave higher grain yield than wheat sown second year after fallow. But most important was to observe that chickpea proved to be of the same value for consecutive wheat as alfalfa. This is explained by the fact that legumes improved nitrogen availability for crop. The fallow increased nitrate content in an arable layer at sowing and heading time by 30-34%, alfalfa - by 41-46%, chickpea - by 34-42%. Very important, that alfalfa's carry over was noticeable during two years, whilst during the second year after fallow the content of nitrates was only 17-25% higher than in continuous wheat. Thus, in the conditions of southern Kazakhstan the best cropping program may include growing wheat during one year after fallow, and two years after alfalfa and one year after chickpea. Chickpea itself gave very low grain yields in dry years: 0.29-0.45 t ha^{-1} and good yield (1.24 t ha^{-1}) in wet year. On average chickpea grain yield was almost half of wheat sown continuously. But anyway the crop can provide good income to farmer, because the market prices are four times higher than for wheat.

In Kyrgyzstan generally adopted crop rotation in dryland farming is practice of summer fallow followed by growing grains two-three years continuously. In the experiment studied were three types of fallow with an attempt to improve it by application of manure or straw. It was also tested against replacement of fallow by sowing crops: chickpea, dry pea and safflower. Most important advantage of summer fallow is believed to be moisture accumulation, but in both years there was no significant difference between fallow treatments in soil moisture content in spring.

Growing of crops reduced soil moisture but not very much: by 12-14%. The wheat grain yield wasn't significantly affected by improved fallow practices and was reduced by replacement of fallow with crop like safflower but not with dry pea (Table 5).

Types of fallow didn't affect significantly wheat yield. Application of manure during fallow period on the background of commercial fertilizer gave some positive result. Most important result was obtained by trying to sow dry pea instead of summer fallow. It was very successful, because the wheat yield was only slightly lower than that after summer fallow. At the same time dry pea produced 1.34 t ha^{-1} of grain without fertilizers and 1.58 t ha^{-1} with fertilizers. Chickpea was tested only in 2002 and provided grain yield comparable to field pea. Safflower seemed to be not the best preceding crop for winter wheat on dry land reducing wheat yield by 24% as compared to fallow, but the safflower crop produced 1.46-1.95 t ha^{-1} of seeds without fertilizer and with it respectively, which definitely compensated some reduction of the wheat yield.

Economical assessment has demonstrated that existing practice of fallow-wheat rotations was the worst

Table 5. Winter wheat grain yield as affected by summer fallow or preceding crops in dryland conditions of Kyrgyzstan.

Fallow or preceding crop	No fertilizer		Mean	Fertilizer		Mean
	2001	2002		2001	2002	
			Grain yield, t ha^{-1}			
Fallow	1.36	2.66	2.01	1.56	3.24	2.40
Fallow+ manure	1.43	2.39	1.91	1.70	3.36	2.53
Fallow+straw	1.28	2.64	1.96	1.48	3.10	2.29
Dry pea	1.29	2.50	1.90	1.48	3.08	2.28
Safflower	0.93	2.19	1.56	1.14	2.51	1.82
LSD_{05}	0.09	0.10		0.09	0.16	

possible scenario for farm profitability. Most important were market prices, which were not in favor of wheat. During harvest of 2002 market prices for 1 ton of different crops were the following: wheat – $130, dry pea – $425, chickpea - $930. Because of this net profit from one hectare of wheat, dry pea and chickpea amounted to $87, $717 and $1355 respectively. Even if the chickpea price would be somewhat lower and farmer would be harvesting chickpea by hand it would be much more profitable than wheat. At this level of difference in favorable year farmer can absorb losses in very dry year if chickpea fails. Remarkably, fertilizers were not profitable for wheat reducing net profit per hectare from $87 to $27, whereas application of fertilizer for field pea and chickpea was found profitable, increasing net profit by $28 and $105 respectively.

Discussion

The crop rotation studies have provided new data for improved cropping systems. They have shown in northern Kazakhstan that crop production from total cropland can be increased. More importantly, they lead to a reduction in the area under summer fallow. This will have a positive environmental effect as summer fallow causes wind and water erosion. The recommendations of scientists justifying fallow usually recognized this danger but recommended to practice strip-cropping. Actually this recommendation was never carefully followed in the Soviet Union and completely stopped after the system of governmental control was replaced by private farming. Today this practice is more like weedy fallow because farmers don't have the resources to cultivate fallow during the summer.

The experiment was laid out on rather small plots, where soil processes were observed purely with no interference of wind erosion, while large commercial farms in the region fallow standard 400 hectares fields. According to Eskov (1996), 80-90% of soil humus losses in northern Kazakhstan are associated with soil erosion. According to Shiyatiy (1996), summer fallow fields erode most during snowmelt runoff. If soil losses from runoff on wheat stubble of southern chernozem are equal to 1, then this coefficient after summer fallow would be 33. In the spring of 1983, he observed that intensive runoff of snowmelt on fallow caused rill erosion as deep as 10-20 cm and soil losses of 60 to 450 t ha^{-1} in wash-out area. The conservation tillage using regular equipment for weed control during fallow destroys all wheat crop residues (1.5-2 t/ha) after three operations, whereas at least four tillage are done during the season.

In a number of studies in northern Kazakhstan and in Siberia, soil nitrates were observed to leach during fallow to a depth of 3-5 m and deeper (Kiryushin, 1996). Summarizing studies in these two regions, the author concluded that more frequent summer fallow leads to greater nitrogen losses, especially under intensive mechanical soil tillage and insufficient phosphorus fertilizer. At Shortandy, organic matter losses were not substantial during 35 years and depended on frequency of fallow (Akhmetov et al., 1998). After 35 years, under wheat-fallow rotations with 50, 33 and 25% fallow, a loss of organic matter made 10%, 11% and 2% of original humus respectively since 1962, when humus content comprised 3.9%. Under six-field rotation (17% fallow) and under continuous wheat, no changes were observed at all. It should be noted, conservation tillage in combination with straw spreading of the harvested crop was used during all years of the experiment.

The issue of reduction of area under summer fallow raised by Suleimenov (1988) 15 years ago has not been accepted by scientists of Kazakhstan in spite of 20 year data supporting it. The abstracts of a recent conference in Astana, Kazakhstan indicate that it was just one paper suggesting replacement of black fallow with cover crop fallow for forage production (Konopyanov, 2003). In other paper (Khabirov et al., 2003) it was stated that it was no difference in wheat yield obtained after black fallow and fallow with cover crops oats and oats-pea used for forage, but the authors made no conclusions based on this fact. The practice of summer fallow once in four years was advocated for so long time that nobody wants to oppose it now. Many farmers don't use fallow but scientists still continue to recommend this practice.

Dvurechenskiy (2003) emphasized that summer fallow should occupy 25-33% of area under crop rotation. Shiyatiy (1996a) also concluded that summer fallow should occupy 33% of rotation area. Viurkov (2003) once again recommended that summer fallow practice should include sowing of kulissy (mustard strips sown of fallow land 10-12 m apart in July to produce short barriers) to trap snow drift during second winter of fallow for improving water storage. This kind of practice was recommended by Bakayev (1975) long ago. But it worked well only on small plots. When producers tried it on large scale it caused severe soil erosion by water and was stopped. This is very important issue that many scientists make trials on small plots and test developed technologies on small scale. Later when they are implemented on large areas they may cause serious problems very exceeding advantages they were supposed to bring farmers.

The scientists of western Siberia working in steppe zone also are in favor of summer fallow once in four-five years (Moshchenko and Bormotov, 2000). However Mr. V. Schnider (2002), a farmer recognized as the best farmer of the region, shared that as distinct from other farmers of the region he practices continuous grain cropping: wheat (67%) and course grains barley and oats (33%). Since establishment of the farm in 1994 crop area increased from 1,500 ha to 21,000 ha by renting land from other less successful landowners. This farm is located at the border with the North Kazakhstan province with average amount of precipitation 300 mm. The average grain yield on this farm for 1994-1998 and 1999-2001 amounted to 2.25 t/ha and 1.87 t/ha, respectively or 27% and 21% higher than average in the district fallowing 12.2% of the cropland. One of reasons of his success is been use of John Deer machinery, but the statement that he eliminated summer fallow in contrast to recommendations of scientists is remarkable.

Several alternative crops were found more economical than spring wheat in northern Kazakhstan thanks to low wheat prices. Nevertheless, wheat dominates in the cropping structure even more than before transition (Table 6).

Total sown area in Kazakhstan reduced dramatically affected by remarkable changes in farm size and removal of governmental control, by liberalization of input and output prices. In 2001 it made only 48% to the sown area in 1990. Wheat area reduced by 23% which led to further increase of wheat share in the total crop sown area from 40% in 1990 to 64.6% in 2001. Barley area was contracted by half but its share in cropping system remained the same. The area under other small grains as millet, rye, oats and buckwheat reduced four-five times. Farmers in Kazakhstan stick to one crop because of inertia in spite of low wheat prices several years in a row as distinct from farmers in the western countries ready to produce market demanded crops.

Oilseeds are the only crops increasing sown area during transition alongside with reduction of total sown area. This increase was achieved thanks to two crops: safflower and sunflower. Pulses were the least attractive crops in the past and this picture even has aggravated. Certainly pulses are not for large farms as there are problems with losses during the harvest. But on small area farmer can achieve good yields and generate good profit.

The share of perennial grasses remained at the same level. Perennial grasses include some alfalfa under irrigation but mostly it is crested wheat grass sown first of all on light textured soils for strip cropping to protect wheat from wind erosion. Annual grasses and maize for silage both proved to be uneconomical and its production was stopped very quickly.

Table 6. Change in cropping structure and crop ranking as affected by transition to market economy in Kazakhstan.

1990			2001		
Crop ranking	'000 ha	% of sown area	Crop ranking	'000 ha	% of sown area
1. Wheat	14.070	40.0	1. Wheat	10.850	64.6
2. Perennial forage	4.568	13.0	2. Perennial forage	2.222	13.2
3. Barley	3.660	10.4	3. Barley	1.751	10.4
4. Annual grasses	3.498	9.9	4. Oilseeds	347	2.1
5. Maize for forage	2.282	6.5	5. Annual grasses	267	1.6
6. Millet (proso)	781	2.2	6. Oats	183	1.1
7. Rye	769	2.2	7. Millet	115	0.7
8. Oats	382	1.1	8. Maize (forage)	72	0.4
9. Oilseeds	266	0.8	9. Buckwheat	57	0.3
10. Buckwheat	218	0.6	10. Rye	44	0.3
11. Pulses	159	0.4	11. Pulses	24	0.1

Certainly, alternative crops will not replace wheat in large scale but they might be essential source of income for small farmers. Most of alternative crops need some special field activities which are not feasible on large farms. Wider adoption of food legumes may contribute also to increased production of plant protein for population of Central Asian countries, which is of especial importance for poor people.

References

Akhmetov, K.A., B. Kanafin, and A. Kiyasov. 1998. Spring wheat yield and soil fertility in the course of long-term use of cropland under wheat – fallow rotations. In: Proceedings of International conference "Soil conserving cropping system and grain production on Eurasian continent in 21st century", Novosibirsk, p. 46-47 (Rus).

Bakayev, N.M. 1975: Soil moisture and crop yield. Alma-Ata: "Kainar" (Rus).

Dvurechenskiy, V. 2003. Soil conserving technology of grain production in northern Kazakhstan. In: Proceedings of the International Conference on Scientific bases of state agricultural production program of Republic Kazakhstan for 2003-2005 (Eds.: K. Elemesov, M. Abdraimov and A. Moldashev), Astana, Kazakhstan, p. 84 (Rus).

Eskov, A. 1996. Development of adaptive cropping systems in Northern Kazakhstan. In: Proceedings of KRIGF " Soil conserving cropping system- Problems and outlook" (Eds.: A.Eskov and E.Shiatiy), Shortandy, p. 6-10 (Rus).

Khabirov, M., T. Blisov and C. Tokmagambetov. 2003. Productivity of field crop rotations on dark chestnut soils of Akmola province. In: Proceedings of the International Conference on Scientific bases of state agricultural production program of Republic Kazakhstan for 2003-2005 (Eds.: K. Elemesov, M. Abdraimov and A. Moldashev), Astana, p. 134 (Rus).

Kiryushin, V. 1996. Ecological bases of cropping systems. Kolos, Moscow (Rus).

Konopyanov, A. 2003. Efficiency of field crop rotations in northern Kazakhstan. In: Proceedings of the International Conference on Scientific bases of state agricultural production program of Republic Kazakhstan for 2003-2005 (Eds.: K. Elemesov, M. Abdraimov and A. Moldashev), Astana, p. 127 (Rus).

Moshchenko, Y. and I. Bormotov. 2000. Development of principles of steppe cropping system. In: Proceedings of the International Conference on Energy and resource conservation in the cropping systems of arid territories, Barnaul, Russia, pp. 135-139 (Rus).

Shiyatiy, E. 1996. Improvement of soil conserving measures – the base for progress in crop production. In: Proceedings of KRIGF " Soil conserving cropping system- Problems and outlook" (Eds.: A.Eskov and E.Shiatiy), Shortandy, pp. 20-33 (Rus).

Shiyatiy, E. 1996a. Three field grain-fallow crop rotations in steppe of Kazakhstan. J. Zemledeliye, 6: 15-18 (Rus).

Schnider, V. 2002. Large grain farm of Siberia. J. Economics of agriculture of Russia, 11: 8 (Rus).

Suleimenov, M.K. 1988. About theory and practice of crop rotations in northern Kazakhstan. J. Zemledeliye, 9: 20-24 (Rus).

Viurkov, V. 2003. Tillage for reproduction of soil fertility in grain-fallow rotations of near Ural area. In: Proceedings of the International Conference on Scientific bases of state agricultural production program of Republic Kazakhstan for 2003-2005 (Eds.: K. Elemesov, M. Abdraimov and A. Moldashev), Astana, p. 119 (Rus).