Effect of Potassium Chloride Application for Rice, Cotton and Potato in the Irrigated Zone of Kazakhstan

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Over the past two decades a sharp deficit of all nutrients, especially K, has been observed in Kazakhstan. Field trial results indicated a strong positive response to KCl for potato and rice, and a modest response for cotton.

Trend analysis of mineral fertilizer consumption in Kazakhstan shows that N and P fertilizers are of primary importance both in terms of use and supply. Potassium holds a significantly distant third position. Low domestic supply can be somewhat related to an absence of potash production within the country; but the general low use of KCl can also be associated with results of soil tests conducted by the State Agrochemical service, which historically suggest that arable soils are high in K.

The role of K in improving crop productivity is underestimated in Kazakhstan (Mineev, 1999). Research on the effectiveness of KCl on different crops grown within its soil-climatic zones is of particular interest to growers in Kazakhstan because of the potential to not only increase crop yields, but also to improve quality.

A demonstration of the effect of K rate on the yield of potato tubers.

Cotton is a very important crop in Kazakhstan and cotton lint is one of the top agricultural exports. It is sown on approximately 150,000 ha located in the southern region. The crop is grown under irrigation, which allows farmers to obtain high lint yields. Cotton has a long growing season and high yielding plants demand large amounts of K. With average crop productivity, cotton removes 150 kg K_2O/ha. Cotton is especially sensitive to soil K deficits during the vegetative growth period (Suleimenov, 2008; Umbetaev et al., 2008).

One of the most important irrigated crops in Kazakhstan is rice. Its current sown area is about 90,000 to 100,000 ha. Expansion of rice-swamp soils of the Akdalinski irrigational massif reclamation has, over time, led to an increase in areas with low plant available N, P and K (Otarov et al., 2004). Modern high-yielding rice varieties require high rates of K (Esimbekov et al., 2005).

In Kazakhstan, potato grows on an area of about 170,000 ha. The crop also needs a lot of nutrients for normal growth and development. The nutrient removal from a 10 t tuber harvest plus aboveground growth is commonly 60 to 80 kg N, 15 to 22 kg P_2O_5 and 100 to 140 kg K_2O (Aitbaev et al., 2005; Aitbaev, 2010). Potato has a high demand for K and responds well to K fertilizers at different levels of exchangeable K content in soils (Eleshev et al., 2011).

Studies on the effect of KCl on cotton, rice and potato yield were conducted by the Soil Science and Agrochemistry Science Research Institute in south and southeast Kazakhstan in 2009-2011. Field trials with cotton were carried out on experimental fields of the Kazakh Cotton-growing Research Institute, on light grey soils. Rice was sown in the Almaty region on experimental plots on rice-swamp soils. The experiment with potato was conducted on experimental fields of the Kazakh Research Institute on dark chestnut soils in the Almaty region.

Experimental sites were calcareous, loam-textured, low organic matter (OM) soils with high pH values (8.2 to 8.5). The rice-marsh soils had very low OM in the 0 to 40 cm layer (1.83%), 45 mg/kg hydrolysable N, 11.3 mg/kg available P_2O_5, 315 mg/kg exchangeable K_2O, (medium), and a total base saturation of 15 to 17 mg per 100 g soil. Light grey soils had 0.59% OM with 35.3 mg/kg of hydrolysable N, 32.2 mg/kg available P_2O_5 (medium), 303 mg/kg of exchangeable K_2O, and a total base saturation of 15 to 17 mg per 100 g of soil. The dark chestnut soils has 2.21% OM, 80.7 mg/kg hydrolysable N, 88.5 mg/kg of available P_2O_5 (high), 650 mg/kg of exchangeable K_2O (high), and a base saturation of 21 to 23 mg per 100 g of soil.

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium; KCl = potassium chloride.

Cotton and potato were cultivated under irrigation, and rice under full flooding. Cotton and rice were cultivated in monoculture; potato was planted after tomatoes within a vegetable crop rotation.

Ammonium nitrate (34% N) was the N source for cotton and potato, and ammonium sulfate (21% N) was used in rice. Nitrogen application was done in two splits: 30% at planting and 70% as a top-dressing. Phosphorus and K were applied as triple superphosphate (46% P_2O_5) and KCl (60% K_2O) prior to planting. The content of exchangeable K and plant available P were determined using 1% ammonium carbonate $(NH_4)_2CO_3$ solution (Machigin method for calcareous soils).

Table 1. Fertilizer application rates (kg/ha) for cotton, rice and potato.

Treatment	Cotton	Rice	Potato
Control	-	-	-
T2	K_{60}	K_{40}	K_{70}
T3	$N_{150}P_{90}$	$N_{180}P_{90}$	$N_{90}P_{90}$
T4	$N_{150}P_{90} + K_{30}$	$N_{180}P_{90} + K_{20}$	$N_{90}P_{90} + K_{35}$
T5	$N_{150}P_{90} + K_{60}$	$N_{180}P_{90} + K_{40}$	$N_{90}P_{90} + K_{70}$
T6	$N_{150}P_{90} + K_{90}$	$N_{180}P_{90} + K_{60}$	$N_{90}P_{90} + K_{105}$

Soil samples were collected at both 0 to 20 cm and 20 to 40 cm depths before the initiation of experiments, during flowering, and at crop maturity. Treatments and fertilizer application rates are shown in **Table 1**.

Crop K Response

Cotton lint yields showed a significant response to fertilizer application (**Table 2**). However, sole application of K only increased lint yield by 0.2 t/ha beyond the control plot yield of 2.7 t/ha. Significantly higher lint yields with NPK application, beyond that achieved with N and P alone (3.2 t/ha), was obtained with 90 kg K_2O (3.5 t/ha).

Table 2. The effect of fertilizer application on cotton, rice and potato yields in south and southeastern Kazakhstan.

	Yield, t/ha		
Treatment	Cotton	Rice	Potato
Control	2.7	2.5	13.9
T2	2.9	2.9	18.0
T3	3.2	3.6	23.0
T4	3.4	3.9	26.6
T5	3.4	4.2	27.0
T6	3.5	4.4	27.6
$LSD_{0.05}$	0.3	0.3	1.7

Cotton-growing soils in the region have relatively high soil test K, which has led to the belief that the use of K fertilizer would be ineffective. However, recent research is showing that application of high rates of N and P fertilizer, providing yields above 3.5 t/ha, increases K efficiency. This positive effect is not only observed on areas with low K availability, but also on soils with medium and even high K content (Umbetaev et al., 2008).

In rice, any K application led to the significantly more grain yield compared to the control plot yield of 2.5 t/ha. The effect of N and P, without K, was greater than K alone. The 40 kg K_2O/ha rate proved most effective in combination with the N and P rates tested as the 60 kg/ha rate did not offer any statistical advantage in terms of yield.

Potato productivity was also impacted by K application as 70 kg K_2O/ha, alone, raised tuber yields by 4.1 t/ha beyond the average control plot yield of 13.9 t/ha. Application of 35 kg K_2O/ha together with N and P proved most beneficial in terms of yield since further increases in K rate up to 105 kg K_2O/ha did not prove to be advantageous.

Agronomic Efficiency

The agronomic efficiency (AE) of K for cotton remained high across treatments producing a range of 4 to 6 kg of lint per kg K_2O (**Table 3**). For rice, the range of AE values were also high across K rates up to 60 kg K_2O/ha and ranged between 13 to 15 kg of grain per kg K_2O. For potato, results varied more broadly across rates and ranged from 41 to 94 kg of tubers per kg of K_2O/ha, but this range is indicative of a high response of potato to K application.

Table 3. Agronomic efficiency of K fertilizers in south and southeastern Kazakhstan.

Treatment	kg cotton lint per kg K_2O applied	kg rice grain per kg K_2O applied	kg potato tuber per kg K_2O applied
T3	-	-	-
T4	6	15	94
T5	4	15	53
T6	4	13	41

Economic Efficiency

The data showed considerable economic efficiency of KCl on potato, followed by rice and cotton (**Table 4**). Net profit over K fertilization of potato grew from US$1,898 to 2,008 per ha with K rates between 35 to 105 kg K_2O/ha. Similarly, 20, 40 and 60 kg K_2O/ha in rice gave net return of $468, $667 and $772 per ha, respectively. Net profit from K applied in cotton amounted to $133, $155 and $210 per ha at rates of 30, 60 and 90 kg K_2O/ha, respectively.

Table 4. Economic efficiency of K fertilizers in south and southeastern Kazakhstan.

Treatment	Net profit over K, US$/ha	Value cost ratio (VCR_K)
Potato		
T4	1,898	18.9
T5	1,936	10.6
T6	2,008	8.2
Rice		
T4	468	11.6
T5	667	11.8
T6	772	10.5
Cotton		
T4	133	4.5
T5	155	3.2
T6	210	3.2

In potato, large value-to-cost ratios (VCR) were obtained, which varied from 8.2 to 18.9. Generally, an economically reasonable VCR should be above 3.0 (Sommer et al., 2013). For rice, VCR was very similar at the three K levels and ranged from 10.5 to 11.8. In cotton, VCR was 4.5 at 30 kg K_2O/ha and was 3.2 at both the 60 and 90 kg K_2O/ha rates.

Summary

Results show high efficiency of KCl application together with NP fertilizers on cotton, potato and rice, which are culti-

vated under intensive irrigated conditions. As a main outcome from this research, new fertilizer recommendations for K have been developed. Depending on the level of exchangeable K the following rates are recommended:

1. For rice yields of 4.0 to 5.0 t/ha—on soils with low exchangeable K use 30 to 60 kg/ha of K_2O, and 30 kg/ha of K_2O for medium testing soils. Among K fertilizers, KCl is the most efficient source. On saline soils, the rate of K application should be reduced by 10 to 15%.
2. For cotton lint yields of 3.5 to 4.0 t/ha—on low K soils, such as the light grey soils, 60 to 70 kg/ha of K_2O is required; high K soils need 30 to 40 kg K_2O; medium K soils need 40 to 50 kg K_2O.
3. For potato grown on dark chestnut soils with high soil test levels (>400 mg/kg) use 40 to 60 kg/ha of K_2O; low K soils require 110 to 120 kg of K_2O/ha. BC

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