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.

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 K₂O/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 P₂O₅, and 100 to 140 kg K₂O (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 P₂O₅, 315 mg/kg exchangeable K₂O (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 P₂O₅ (medium), 303 mg/kg of exchangeable K₂O, 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 P₂O₅ (high), 650 mg/kg of exchangeable K₂O (high), and a base saturation of 21 to 23 mg per 100 g of soil.
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% P2O5) and KCl (60% K2O) prior to planting. The content of exchangeable K and plant available P were determined using 1% ammonium carbonate (NH4)2CO3 solution (Machigin method for calcareous soils).

Statistical advantage in terms of yield.

The N and P rates tested as the 60 kg/ha rate did not offer any advantage.

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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cotton</th>
<th>Rice</th>
<th>Potato</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
<td>K0</td>
<td>K0</td>
<td>K0</td>
</tr>
<tr>
<td>T2</td>
<td>N150P90 N90</td>
<td>N180P90 N90</td>
<td>N150P90 N90</td>
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<td>T3</td>
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<tr>
<td>T6</td>
<td>N150P90 K30</td>
<td>N180P90 K20</td>
<td>N150P90 K35</td>
</tr>
</tbody>
</table>

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 K2O (3.5 t/ha).

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 K2O/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 K2O/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 K2O/ha together with N and P proved most beneficial in terms of yield since further increases in K rate up to 105 kg K2O/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 K2O (Table 3). For rice, the range of AE values were also high across K rates up to 60 kg K2O/ha and ranged between 13 to 15 kg of grain per kg K2O. For potato, results varied more broadly across rates and ranged from 41 to 94 kg of tubers per kg of K2O/ha, but this range is indicative of a high response of potato to K application.

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 K2O/ha. Similarly, 20, 40 and 60 kg K2O/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 K2O/ha, respectively.

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 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 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 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 8.2 to 18.9. Generally, an economically reasonable VCR should be above 3.0 (Sommer et al., 2013).

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 K₂O, and 30 kg/ha of K₂O 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 K₂O is required; high K soils need 30 to 40 kg K₂O; medium K soils need 40 to 50 kg K₂O.

3. For potato grown on dark chestnut soils with high soil test levels (>400 mg/kg) use 40 to 60 kg/ha of K₂O; low K soils require 110 to 120 kg of K₂O/ha.

The author acknowledges help from Dr. S. Ivanova, Vice President, Eastern Europe & Central Asia Group and Director, IPNI Central Russia Region, with the preparation of this article.

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