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The effects of ammonium phosphate fertilization on yield and yield components of Mustard varieties in chernozem soil

Bibigul Khamzina [a], Berdibek Bulashev [a], Yerbol Nurmanov [a,*], Tamara Tultabayeva [a], Nurgul Nurmukhanbetova [b], Dana Toimbayeva [a], Ayazhan Igimbay [b], Gulnar Myrzabayeva [c]

[a] S.Seifullin Kazakh Agrotechnical University, Astana, Kazakhstan
[b] Shoqan Ualikhanov Kokshetau University, Kokshetau, Kazakhstan
[c] Kazakh National Agrarian Research University, Almaty, Kazakhstan

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Author(s)

B.Khamzina
B.Bulashev
Y.Nurmanov *
T.Tultabayeva
N.Nurmukhanbetova
D.Toimbayeva
A.Igimbay
G.Myrzabayeva

* Corresponding author

Abstract

Mustard seed is primarily used in the food or condiment industries in the form of either ground seeds or oil, and plays a significant role in agriculture. Especially in the intensive agricultural system where chemical fertilizers are used, little is known the impact of ammonium phosphate (Ammophos, 12% N, 52% P_2O_5) fertilizer applications on the yield and yield component of mustard under chernozem soil conditions. The objective of this study was to investigate the effects of seven doses of ammonium phosphate fertilizer applications on the seed yield and yield components of two different mustard varieties [Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.)] under chernozem soil conditions in Northern Kazakhstan. According to field experiment results, there were significant differences among the treatments in relation to yield and yield components (oil content, dry matter accumulation, NPK uptake, NPK contents in seeds) of mustard varieties. The higher seed yield for the $N_{34.6}$ P_{150} treatment in Rushen and $N_{41.5}$ P_{180} treatment in Profi than for any of the other rates of ammonium phosphate fertilizer application under the agro-ecological conditions of Akmola region, Northern Kazakhstan.

Keywords: Mustard, chernozem soil, nutrients, fertilizer, ammonium phosphate.

Introduction

Mustard is an annual, cool-season specialty cash crop that has a short growing season and is commonly grown in rotation with small grains. Mustard is the name given to two closely related species in the Brassica family. There are over 40 varieties of mustard worldwide, and the most popular are black, brown, and white mustard seeds. Two types of mustards such as brown mustard (Brassica juncea Czern) and yellow mustard (Sinapis alba L.) are cultivated in Kazakhstan. Chernenok et al., (2017) provided a critical review on the necessity to study mustard in the steppe zone of Kazakhstan, where the biological features of mustard allow growing under arid and harsh climatic conditions for seed, also as a forage and green manure. Importantly, mustard is undemanding to soil conditions and heat which is the advantage of growing mustard in the steppe zone of Kazakhstan. Mustard is widely used as a good precursor for cereal crops because it prevents soil erosion, and it is a natural fumigant against weeds, diseases, and soil-born pests. During the introduction of mustard to Kazakhstan's forest-steppe zone and irrigated land conditions, the primary attention was paid to mustard biology, breeding, cultivation technology, and crop fertilizers (Ivankova, 2004; Grishanov, 2009).

Soil conditions affect the productivity of mustard seeds and green mass, which provide nutrients and moisture. Soil fertility depends on the primary nutrient status of the soil and the application of fertilizers. Other studies were carried out in this direction, making it possible to study in the context of a regional character. Some of them showed that the application of fertilizers for mustard affects the crop yield and its

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profitability, which is a decisive factor (Chand et al., 2006; McKenzie et al., 2006; Sefaoğlu et al., 2021). Amongst many others, the nutritional requirements of the crop are considered to be the most important factor.

Nitrogen and phosphorous fertilizers play a vital role in enhancing mustard yield, in that they form the basis of photosynthetic processes, cell growth, metabolism, and protein synthesis (Chapin et al., 2000). Not only the amount of the nutrients in the soil but also the nutrient balance is important for producing agricultural plants in a high quality and quantity (Sefaoğlu et al., 2021). A high rate of N application increases leaf area development, improves leaf area duration after flowering and increases overall crop assimilation, thus contributing to increased seed yield (Wright et al., 1988). Patel et al. (2004) reported that as the dose of nitrogen increased the oil content of Indian mustard decreased and its seed yield increased. Phosphorus is the second most deficient nutrient element after nitrogen in terms of plant productivity in soils. Rodríguez et al. (2000) reported that the leaf area decreased by 83% and photosynthesis efficiency decreased by 50% in the plants grown under phosphorus stress.

Chernozem soils in North Kazakhstan occupy 25.3 million ha and are the most productive soils of the country. An area of approximately 11 million ha of Chernozem soil was planted annually with spring wheat (Triticum aestivum L) during the Soviet period when the political aim of a rapid increase in grain production was achieved by indiscriminate plowing of as large an area of virgin lands as possible (Karbozova–Saljnikova et al., 2004). Chernozem soils are a valuable resource because of their extent and because they are fertile. Chernozems must be properly managed and protected for efficient and sustainable productivity. They have been researched in the past but mainly as a soil-geographic resource. Further study is needed to quantify and expand their value in production and assure environmental sustainability (Saparov, 2014). Many factors are involved in producing a high yield of mustard. Although climatic factors such as rainfall and temperature cannot be controlled, many other critical components of the production system like fertilizer application can be carefully managed. High mustard yields require maintenance of agricultural practices to meet the needs of the rapidly growing crop. As the demand for high yield and oil content closer examinations of the role of proper agricultural practices are needed.

This study was carried out to evaluate the effects of different rate of ammonium phosphate fertilizer application on yield and yield components (oil content, dry matter accumulation, NPK update and NPK contents in seeds) of Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties in chernozem soil of Northern Kazakhstan.

Material and Methods

Study Area

The experiment was performed at LLP Nikolskoye, Bulandinsky district, of the Akmola region, Northern Kazakhstan (52”13’15”N, 70”32’29”E) during the growing season 2020-2021 with a view to finding out the 2 different mustard variety as well as determining the effects of different P fertilizer doses on mustard yield and yield components. This region is characterized by a semi-arid climate. The locations of the evaluations were characterized by the continental climate (large daily and annual fluctuations in air temperature, characterized by cold winters and long hot summers), the air temperature reaches minimum values in January (-15,5^{0}C), and maximum values in July (17,5^{0}C), the average annual temperature is +2.4 ^{0}C and an annual amount of precipitation is 365 mm.

Soil

The main soil type, which is typical for the region, is calcic chernozem or carbonate chernozem soil. The thickness of this chernozem is between 50 cm and 100 cm. There is a horizon with a concentration of secondary carbonates (calcic horizon). The $CaCO_3$ accumulations are in the size of clays or silts. The Soil Taxonomy (USDA, 1975) also admits the presence of a calcic horizon in mollisol with a mineral horizon that is marked by a prefix calci- in the name of the soil. The soil belongs to the general soil type of calcic chernozem. The soil pH was 8.0-8.1, and calcium carbonate ($CaCO_3$) concentration was 0,9%, soil organic matter was 3.8%, total N was 0.25-0.30%, available phosphorus was 15-20 mg/kg and exchangeable potassium was 350-500 mg/kg.

Mustard

The objects of the research were 2 mustard variety, Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.), choose for use. Characteristics of mustard varieties are given Table 1. The characteristics of these mustard varieties allow cultivation under the given conditions and their biological characteristics correspond to cultivation in the studied soil-climatic zone.

Table 1. Characteristics of mustard varieties (Sahay et al., 2015; Singh and Thenua, 2016)

Characteristics of mustard varieties	Rushen (Brassica juncea (L.) Czern.)	Profi (Sinapis alba L.)
Year of release	1992	2011
The vegetation period (days)	82-98	110
The yield of mustard seeds, c/ha	16,0	20,9
Oil contents, %	37,7	37,4
Susceptibility of mustard varieties to diseases	Slightly susceptible to downy mildew	Slightly susceptible to powdery mildew, clubroot of crucifers, weakly to alternaria
Susceptibility of mustard varieties to pests	Very susceptible to cabbage flea	Stable sugar beet nematode
The content of erucic acid, %	None	Available
The content of oleic acid, %	36,0	26,0
The content of linoleic acid, %	19,4	32,0

Treatments and Experimental design

The field experiment was performed using a completely randomized block design with three replications during the 2020-2021. The experimental unit was 54 m² (9 m x 6 m). The sources of fertilizers used were ammonium phosphate (Ammophos, 12% N, 52% P_2O_5). The experiment was performed with the following seven treatments of agricultural practices given in Table 2.

Table 2. Phosphorus fertilizer levels in field experiment

T1	P_0	Control
T2	$N_{13.8}$ P_{60}	115.4 kg ammonium phosphate/ha (13.8 kg N/ha, 60 kg P_2O_5/ha)
T3	$N_{20.8}$ P_{90}	173,1 kg ammonium phosphate/ha (20.8 kg N/ha, 90 kg P_2O_5/ha)
T4	$N_{27.8}$ P_{120}	230,8 kg ammonium phosphate/ha (27.8 kg N/ha, 120 kg P_2O_5/ha)
T5	$N_{34.6}$ P_{150}	288,5 kg ammonium phosphate/ha (34.6 kg N/ha, 150 kg P_2O_5/ha)
T6	$N_{41.5}$ P_{180}	346,2 kg ammonium phosphate/ha (41.5 kg N/ha, 180 kg P_2O_5/ha)
T7	$N_{48.5}$ P_{210}	403.8 kg ammonium phosphate/ha (48.5 kg N/ha, 210 kg P_2O_5/ha)

The land was disk ploughed, harrowed, and leveled with a tractor. Then mustard was sown (10 kg/ha) with a Bourgault 3710 sowing complex. Fertilizer was applied using grain drill. During the field experiment, same agricultural practices used in same plot of experiment and all the cultural practices regarding fertilization, irrigation, weed control, and pest and disease management were conducted as standard regional cultivation practices. Two mustard varieties (Rushen and Profi) were combined with seven phosphorus fertilizer treatments.

Observed parameters

Plant samples were taken from different phenological periods of the mustard plants. Observed analyses parameters in mustard plants were seed yield, oil content, dry matter accumulation, NPK update and NPK contents in seeds. All parameters were measured according to Jones (2001).

Results and Discussion

In this experiment conducted under rainfed condition, the soil moisture content at the phenological periods of Rushen mustard varietry was 25.9 mm (Pre-sowing); 9.6 mm (Budding), 25.2 mm (Flowering) and 9.5 mm (Harvesting) at 0-20 cm soil depth while it was determined that 27.2 mm (Pre-sowing); 12.2 mm (Budding), 15.3 mm (Flowering) and 9.3 mm (Harvesting) in Profi mustard variety. Both Rushen and Profi mustard variety, it was determined that the moisture content in surface soil (0-20 cm) were higher than in 20-40 cm, 40-60 cm, 60-80 cm and 80-100 cm soil depths (Figure 1). In Figure 1, the reserves of productive soil moisture in a meter layer pre-sowing mustard varieties totally 169 mm. It was determined that during the experiment there was a lack of productive soil moisture in the under mustard crops under rainfed condition. Mustard crop is grown in the areas receiving 625-1000 mm yearly rainfall. But, annual amount of precipitation is 365 mm in this research area.

Seed yield and Oil content

In the present study, the seed yield of Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties increased in response to ammonium phosphate fertilizer application relative to the control (T1) and lower rates of application, with maximum yields (2.07–2.22 t ha^{-1}) being attained at the T5 and T6 rate of ammonium phosphate fertilizer application in both varieties (Figure 2).

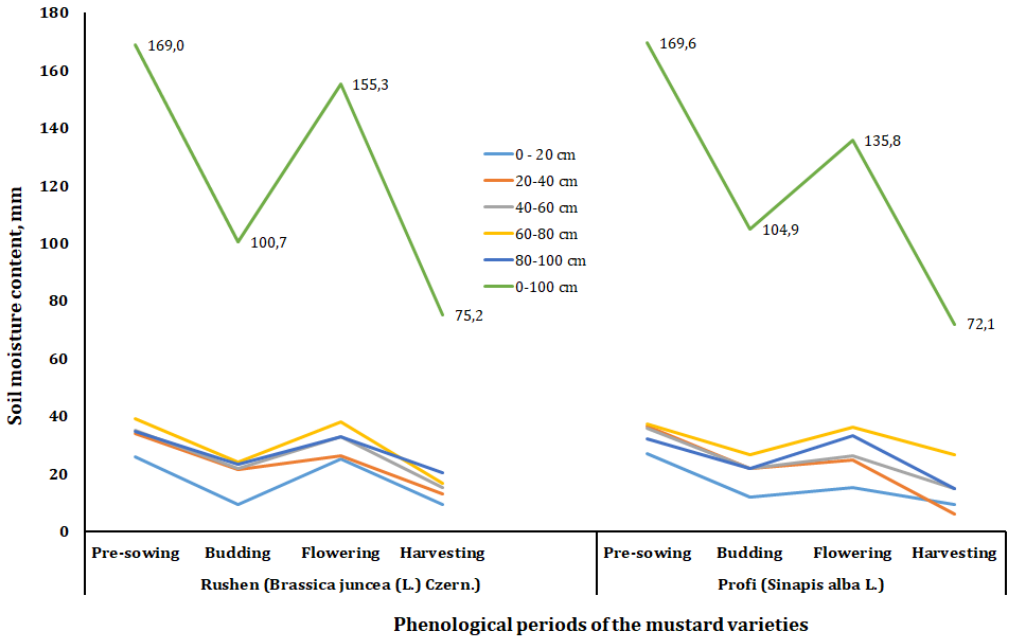

Figure 1. Pattern of soil moisture content during phenological periods of the mustard varieties

Similar yields were reported by other authors (Hocking et al., 1997; Kumar et al., 1997; Nurmanov et al., 2019). Gammellvind et al. (1996) reported a higher seed yield, varying from 2.8 to 4.8 t ha^{-1}, in winter oilseed rape. He also noted a decrease in seed yield at the higher rate of fertilizer application, a result similar to that found in the present study and also by Hocking et al. (1997). The higher seed yield for the T5 treatment in Rushen and T6 treatment in Profi than for any of the other rates of ammonium phosphate fertilizer application. These differences between Rushen and Profi in these yield-determining characteristics were probably associated with significant differences in the leaf area and robust root system of these treatments. This conclusion is supported by the findings of previous studies (Scott et al., 1973; Allen and Morgan 1975; Tayo and Morgan, 1975). The rates of ammonium phosphate fertilizer application affected the oil content in Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties (Figure 2). In Rushen, the highest oil content of 30.4% was found in T5, while in Profi the highest oil content was 37.5% was in T4, this value being significantly higher than the values found in all other treatments, where the difference was statistically non-significant. The higher rates of ammonium phosphate fertilizer application (T6 and T7) reduced the oil content relative to the lower rates of ammonium phosphate fertilizer application. Similar results have been reported in oilseed rape (Asare and Scarisbrick, 1995) and canola (Hocking et al., 1997).

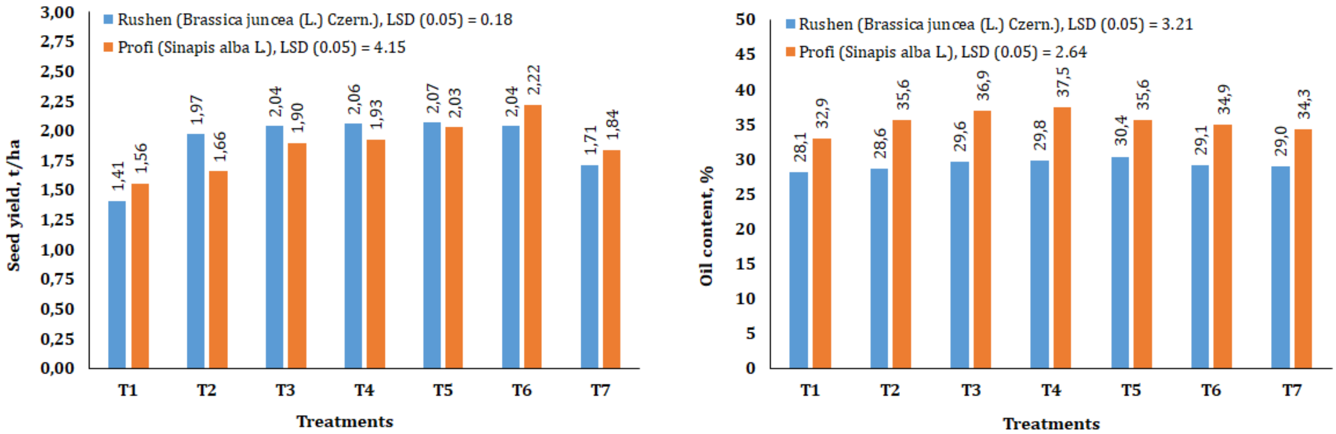

Figure 2. Effect of rate of ammonium phosphate fertilizer application on seed yield (a) and oil content (b) of Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties

Dry matter accumulation

Generally, total dry matter accumulation continued to increase until the full ripeness in Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties (Figure 3) at all treatments. Similar growth curves for total dry matter accumulation in a crops were reported by others (Scott et al., 1973; Allen and

Morgan, 1975; Kjellstrom, 1993; Cheema et al., 2001). The highest rate of ammonium phosphate fertilizer application (T7) gave significantly higher total dry matter than the control (T1) or the lower rates of fertilizer application (T2–F6) in Rushen and Profi mustard varieties (Figure 3). At full ripeness phenological stage of Rushen, the average total dry matter yield was 92.90 in T1, 269.70 in T2, 274.80 in T3, 260.10 in T4, 321.30 in T5, 316.6 in T6 and 414.90 g/100 plants in T7. At full ripeness phenological stage of Profi, the average total dry matter yield was 156.60 in T1, 226.70 in T2, 262.90 in T3, 215.40 in T4, 313.20 in T5, 352.6 in T6 and 387.50 g/100 plants in T7. In these experiments, marked differences in total dry matter yield among different rates of fertilizer application. Kumar et al. (1997) also reported higher total dry matter production with increased rate of fertilizer application. Thus, at any given harvest, the dry matter accumulation is a physiological index closely related to the photosynthetic activity of leaves.

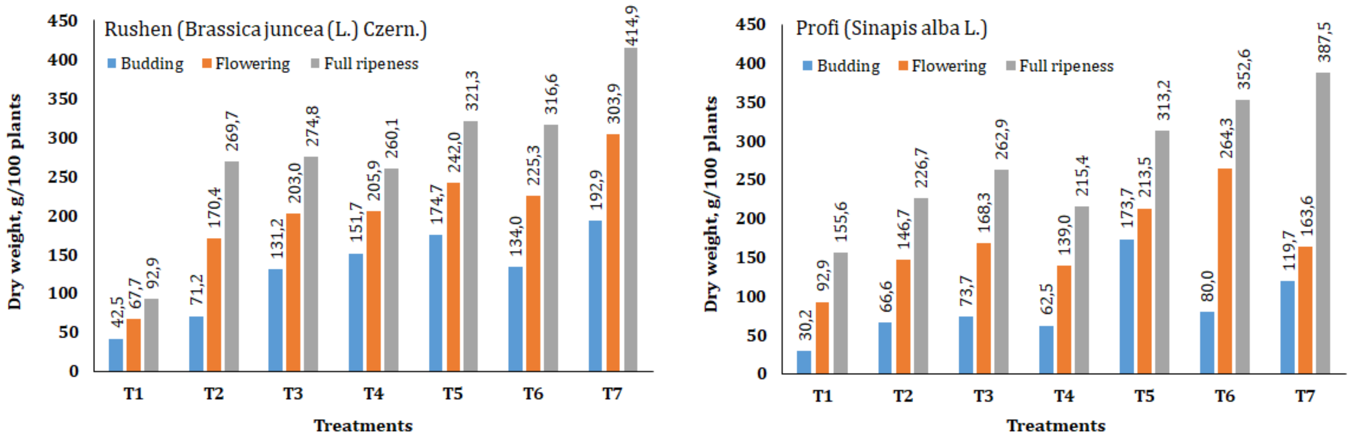

Figure 3. Effect of rate of ammonium phosphate fertilizer application on dry weight of Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties

Nutrient contents in seeds

The effects of different rate of ammonium phosphate fertilizer application on nitrogen, phosphorus, and potassium contents in in seeds of Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties are presented in Figure 4. All of the above parameters were significantly influenced by different rate of ammonium phosphate fertilizer application compared to the control (T1). The total N contents in Rushen and Profi mustard varieties varied from 1.02 to 1.31% (highest content at T2 treatment) and 0.76 to 1.36 % (highest content at T6 and T7 treatments), respectively. The total phosphorus contents in Rushen and Profi mustard varieties varied from 0.54 to 0.65 % (highest content at T6 treatment) and 0.56 to 0.78% (highest content at T7 treatment), respectively. Finally, the total K contents in mustard varieties ranged from 1.26 to 1.47 % for Rushen (highest content at T6 treatment) and 0.86 to 0.93% for Profi (highest content at T6 treatment) under different rate of ammonium phosphate fertilizer application. Al-Taey et al. (2018) recorded that the application of fertilizers can improve plant growth and increase of N, P and K contents in tissue and their uptake. Gülser et al (2021) and Kızılkaya et al. (2022) reported that fertilizers consist of N, P, K increase the uptake and utilization of nutrients by grain crops.

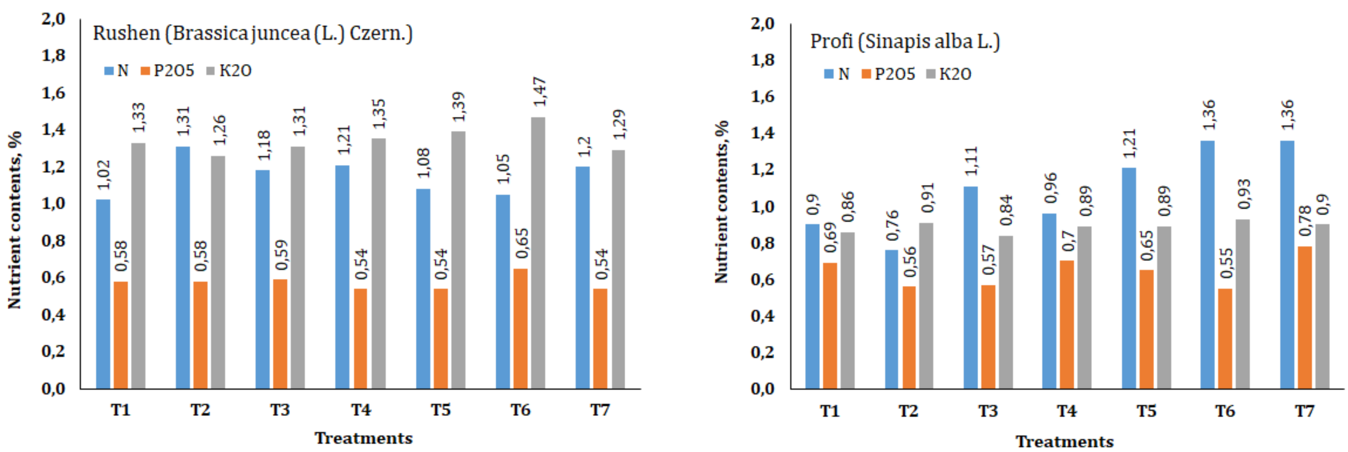

Figure 4. Total N, P and K contents in seeds of Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties affected by different rate of ammonium phosphate fertilizer application ($LSD_{0.05}$ value: 0.10 N, 0.03 P2O5 and 0.04 K_2O for Rushen, 0.70 N, 0.03 P_2O_5 and 0.03 K_2O for Rushen)

Nutrient uptake

Total N, P and K uptake in aboveground plant parts of Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties under different rate of ammonium phosphate fertilizer application are shown in Figure 5. Total N uptake was enhanced under ammonium phosphate fertilizer application compared with control (T1). The total N uptake by Rushen and Profi mustard varieties varied from 14.4 to 25.8 kg ha^{-1} (highest uptake at T2 treatment) and 12.9 to 26.4 kg ha^{-1} (highest uptake at T6 treatment), respectively. The total N uptake during the experiment was higher for the ammonium phosphate fertilizer applications than control. Phosphorus uptake in both Rushen and Profi mustard varieties was greater under ammonium phosphate fertilizer application compared with control. The total phosphorus uptake by Rushen and Profi mustard varieties varied from 6.6 to 13.3 kg ha^{-1} (highest uptake at T6 treatment) and 8.2 to 13.2 kg ha^{-1} (highest uptake at T5 treatment), respectively. Finally, the total K uptake by mustard varieties ranged from 17.9 to 29.4 kg ha^{-1} for Rushen (highest uptake at T5 treatment) and 12.5 to 20 kg ha^{-1} for Profi (highest uptake at T6 treatment) under different rate of ammonium phosphate fertilizer application. These results were in agreement with previous studies (Pan et al., 2012) that reported that yield components were affected by the fertilizations, and consequently, crop yields were usually greater depending on the soil fertility (Hossain et al., 2005). A close positive correlation between nutrient uptake and crop yield has also been reported previously (Witt et al., 2000). The highest mustard yields were observed at theT5 and T6 treatments, due to their correspondingly higher N, P and K uptakes. In addition to the nutrient uptakes, consideration was also given to their interactions. Many researchers have observed the complicated interactions among N, P and K in crop productivity (Yang et al., 2007). In our study, P and K uptake was higher when applied with N, as evidenced by greater P and K accumulation in ammonium phosphate fertilizer application than in control, which clearly indicates the synergistic effect of N on P and K uptake. Our results revealed that T5 ($N_{34.6}$ P_{150}) for Ruslen and T6 ($N_{41.5}$ P_{180}) for Profi application was best at improving the yield and nutrient accumulations for fertilization.

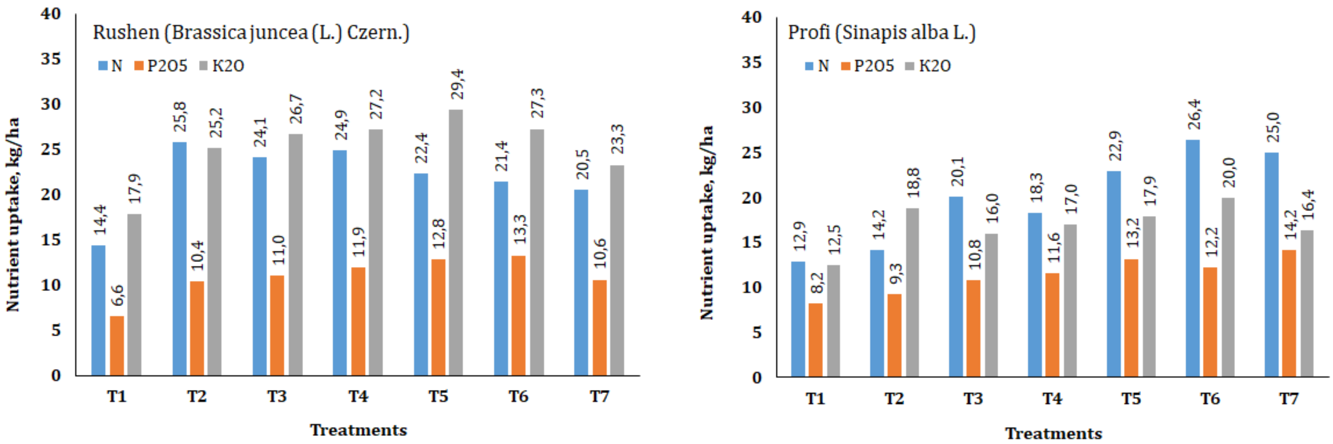

Figure 5. Total N, P and K uptake (kg ha^{-1}) by aboveground parts of Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.) mustard varieties affected by different rate of ammonium phosphate fertilizer application

Conclusion

Two mustard varieties (Rushen (Brassica juncea (L.) Czern.) and Profi (Sinapis alba L.)) and different rate of ammonium phosphate fertilizer application were used to investigate effects on yield and yield parameters of mustard under chernozem soil conditions in the Kazakhstan. It was evident that increased levels of ammonium phosphate resulted higher growth performance in all mustard varieties than control. The higher seed yield for the T5 treatment ($N_{34.6}P_{150}$) in Rushen and T6 treatment ($N_{41.5}$ P_{180}) in Profi than for any of the other rates of ammonium phosphate fertilizer application. The higher rates of fertilizer application (T6 and T7) reduced the oil content relative to the lower rates of fertilizer application.

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