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Effects of nitrogen, phosphorus, and potassium base fertilizers on growth and yield of *Taraxacum kok-saghyz* Rodin

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Taraxacum kok-saghyz (TKS) is a promising natural rubber plant. In the current study we investigated effects of nitrogen, phosphorus, and potassium base fertilizers on growth and yield of TKS through the field experiments. We found that appropriate application of nitrogen, phosphorus, and potassium base fertilizers can significantly increase root, rubber and total sugar yield of TKS. The TKS rubber yield enhanced significantly when the amount of nitrogen and phosphorus, potassium increased accordingly to 107.2, 10.5 and 35.3 g m^{-2}. Maximum accumulation of rubber in the TSK roots is caused by application of potassium fertilizer.

According to the obtained results the recommended amount of base fertilizers under conditions of Harbin Experimental Station (N45.592729°, E126.581668°) is 107.2 g m^{-2} of urea, 43.4 g m^{-2} of calcium superphosphate, 10.5 g m^{-2} of potassium chloride.

Keywords: fertilizer effects, rubber, sugar, leaf biomass

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ИЗУЧЕНИЕ И ИСПОЛЬЗОВАНИЕ ГЕНЕТИЧЕСКИХ РЕСУРСОВ РАСТЕНИЙ

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Влияние азотных, фосфорных и калийных удобрений на рост и урожайность *Taraxacum kok-saghyz* Rodin

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Кок-сагыз (*Taraxacum kok-saghyz* Rodin) – многолетнее травянистое растение, перспективное в качестве источника натурального каучука. Данное исследование описывает влияние азотных, фосфорных и калийных удобрений на рост и урожайность кок-сагыза при помощи эксперимента в полевых условиях. Мы обнаружили, что правильное внесение азотных, фосфорных и калийных удобрений может значительно увеличить урожайность корней, выход каучука и общего сахара у кок-сагыза. При внесении количества азотно-основного удобрения, увеличенного с 0 до 107,2 г м$^{-2}$, тенденция изменения урожайности каучука соответствовала явному увеличению; при внесении количества фосфорно-основного удобрения, увеличенного с 0 до 10,5 г м$^{-2}$, тенденция изменения урожайности каучука также соответствовала значительному увеличению; при внесении удобрения на основе калия, увеличенного с 0 до 35,3 г м$^{-2}$, тенденция изменения урожайности каучука соответствовала наибольшему увеличению.

Согласно нашим рекомендациям, в местных почвенных условиях экспериментальной станции в Харбине (N45.592729°, E126.581668°) количество основного удобрения должно составлять: 107,2 г м$^{-2}$ мочевины, 43,4 г м$^{-2}$ суперфосфата кальция, 10,5 г м$^{-2}$ хлористого калия.

Ключевые слова: кок-сагыз, азот, фосфор, калий, базовое удобрение, каучук

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Introduction

Taraxacum kok-saghyz Rodin (TKS) is a perennial plant which belongs to the *Taraxacum* genus of the Asteraceae family. Its root contains 2.89–27.89% of rubber (Whaley, Bowen, 1947; Luo, 1951; Shen et al., 2018; Shen et al., 2019) and 25–40% of inulin (Polhamus, 1962). TKS leaves also have high antioxidant potential because of their rich total phenolic, tannic phenolic, and total flavonoid content (Kong et al., 2021). Because of its short growth cycle, TKS can be a model plant for natural rubber synthesis mechanism investigation (Schmidt et al., 2010). Therefore, TKS is a plant of high economic and scientific importance.

Numerous studies have shown that fertilizers are very important for growth and yield of TKS. Among the essential nutrients, nitrogen (N) is the most important, followed by magnesium and potassium (K). The influence of calcium and phosphorus (P) is relatively small. The non-essential nutrients – boron and zinc – also have a certain impact on rubber production (Meyer, 1945).

Nieman (Luo, 1951) pointed out that a small amount of N fertilizer can increase rubber content and yield of TKS roots, but excessive amount of N fertilizer will reduce them; N sometimes reduces the sugar content, while P and K promote the sugar accumulation. Coster's results showed that fertilization does not increase rubber content and root yield; another ones argue that the effect of N fertilizers depends on the local soil and climatic characteristics (Whaley, Bowen, 1947; Luo, 1951; Stepanov et al., 1952). For example, P increases the rubber content in humid climates, while under dry climate conditions has the reverse effect (Luo, 1951). The interaction between nutrient elements has not been sufficiently studied, but some investigations have pointed out that the rubber yield can be most effectively improved when the ratio of N and P is 1 : 1. Previous recommendations on N, P, and K application are about 56 kg of nitrogen, 148 kg of P, and 99 kg of K per hectare. The time and depth of fertilization are also important. Most of the fertilizers should be applied into the soil already prepared to the spring sowing in autumn. The optimal time for the first fertilization is the stage of third leave formation; for the second, when the flower buds are formed. The depth of the first fertilization is 3.8–5.1 cm, and of the second 10.2–11.9 cm (Luo, 1951). The experiment conducted by the U.S. Department of Agriculture in 1942–1943 showed that additional fertilizers added in the soil with sufficient nutrition didn't affect the rubber accumulation in the TKS roots, but reduced the TKS roots yield. For a guaranteed high yield of TKS roots, rubber and seeds, Luo suggested the following fertilizer application scheme: P application should be in the spring (before sowing), ½ N and K before the flowering, ¼ N and K during the budding, and ¼ N and K at the full blooming stage. The current study is relevant in connection with the following:

First, although there are many studies into the effects of N, P, and K on TKS development, most of the TKS investigations were carried out before 1960, and researchers paid more attention to the impact of fertilizers on rubber yield, and less on the content of other components and sugars. Secondly, the climate affects the crop's nutrient requirements, which continues to be relevant. Currently, much attention is paid to the application of fertilizers.

Researchers indicated that N, P, and K should be applied three times: basal and two top-dressing fertilization at the 3-4 real leaves and budding stage (Luo, 1951; Stepanov, 1952; Bruulsema et al., 2012).

Crop fertilization is generally divided into base and top-dressing fertilizer application. The base fertilizer satisfies the nutritional needs of crops throughout the growing season, especially in the early stages of development. Top dressing fertilization is necessary during the critical period of plant development. Therefore, the efficiency of using only the base fertilizer will be relatively low. In the current experiment we studied only the impact of the base fertilizer on the parameters of final TKS yield. The base fertilizer provides nutrients for the entire period of crop growth, and investigating the fertilizer's influence on the indicators of economically significant crops continues to be relevant. The objectives of our research were: assessing the effect of N, P, and K fertilizers on the main indicators of root yield and rubber yield, finding the relationship between the application amount of N, P, K base fertilizers and TKS economically significant indicators, and revealing the fertilizer's optimal amount for each economically significant indicator.

Materials and methods

This experiment was carried out on the experimental station in Harbin (N45.592729°, E126.581668°) in 2015. Harbin has mid-temperate continental monsoon climate with average annual temperature of 4.2°C, annual precipitation of 569 mm, and the frost-free period of 145 days. The soil type is soddy/slightly podzolic. The physical and chemical properties are organic carbon 53.95 g kg^{-1}, total nitrogen 2.04 g kg^{-1}, total phosphorus 0.85 g kg^{-1}, total potassium 26.40 g kg^{-1}, alkaline hydrolysis nitrogen 160.2 mg kg^{-1}, available phosphorus 76.9 mg kg^{-1}, available potassium 302.0 mg kg^{-1}, pH 6.78, bulk density 2.56 g cm^{-3}.

Plant materials

All plant materials were obtained from the K-445 strain introduced from N.I. Vavilov Institute of Plant Genetic Resources, Russia, in 2012. After 2 years of adaptation to the local conditions, the seeds were harvested in 2014, and stored in a refrigerator at 4°C after cleaning. During the experiment, the seeds were planted in a greenhouse in mid-April (16–22°C); the seedlings at the stage of 5–7 leaves were transferred to the field (in July – 1.2 months after germination).

Experimental design

The field was divided into 3 blocks. One block consisted of 12 plots, 36 plots throughout the trial.

Soil preparation and transplanting

Soil was ploughed 30 cm deep and broken finely to make a bed. Each experimental plot (bed), facing east/west, was 1.5 m wide, 12 m long, and 40 cm apart. Each fertilizer was evenly applied into the corresponding bed, then the fertilizer was evenly mixed with the soil. No fertilizer was added into the control plot.

There were three factors: different application amount of nitrogen, phosphorus, and potassium, three levels of each (N as N1, N2, N3, P as P1, P2, P3, K as K1, K2, K3), and one control (CK). Fertilizers added before TKS seedling transplantation were urea ($CO(NH_2)_2$, 46.4% of N), calcium superphosphate ($Ca(H_2PO_4)_2 \cdot H_2O$, 24.2% of P), and potassium chloride (KCl, 52.4% of K). Application amounts of urea were 77, 154, and 231 g m^{-2}, or 35.7, 71.5, and 107.2 g m^{-2} of N; 14.5, 28.9, 43.4 g m^{-2} or 3.5, 7, 10.5 g m^{-2} of P; potassium chloride, 22.5, 45.0, 67.5 g m^{-2} or 11.8, 23.6, 35.3 g m^{-2} of K, respectively. TKS seedlings were randomly transplanted into each bed, the spacing between rows was 30 × 30 cm. Watering and weeding were timely applied.

Determined methods

Every 20 days, growth conditions were checked and 30 plants were randomly selected to measure the crown width and number of leaves. In early November, after the aboveground part withered, the biomass, rubber content, total sugar and reducing sugar content were measured by underground parts' assay.

Soil organic carbon was determined by the potassium dichromate external heating method, total nitrogen by the Kjeldahl method, available nitrogen by the indophenol blue colorimetric method, total phosphorus by the molybdenum antimony anticolorimetric method, total potassium by the sodium hydroxide melting method, available potassium by the sodium acetate extraction method, available phosphorus by the sodium bicarbonate method, and bulk density by the ring knife method. All methods mentioned above were described by Bao (2000). Total sugar content was assessed by the anthrone colorimetry method (Gao, 2006), and rubber content by the mid-infrared Fourier transform method (Liu, 2016). Total sugar yield = Total sugar content × root dry weight/unit field area. Rubber yield = rubber content × root dry weight/unit field area (Gao, 2006; Liu, 2016).

Data processing and analysis

In order to study the influence of each nutrient element on each index of TKS, we used a two-way variance analysis. If the ANOVA results showed a significant effect, a planned comparison was performed, namely, the total variance was decomposed into within-group and between-group effects, respectively. Among them, the influence of within-group was dealt with a trend test to examine the relationship between nutrients and various indicators. We used the trend analysis method and according to the P value ($\alpha = 0.05$) and the proportion of variance (η^2) determined a suitable model. The larger the value of η^2, the more obvious the trend. The specific calculation method refers to the work of Roger E. Kirk (2013). Since the trend analysis was to carry out the variance analysis within the numerical variation range of the current measurement index, the fitted equation model was only applicable to the current numerical range. The between-group effect was examined to determine the significance of the difference between each treatment and the control to determine the optimum amount of fertilization. If it could not be determined, a post-hoc comparison was performed, and the Bonferroni method was used for statistical methods. For the specific calculation method, we referred to Roger E. Kirk (2013). We used R language (Core, 2020) to perform data preprocessing, variance analysis, trend test in the R Studio (R Studio Team, 2015) environment, and finally we used the ggplot2 (Wickham, 2016) library in the R language combined with the patchwork library to plot.

Results and analysis

N base fertilizers. Crown diameters of TSK treated with N base fertilizers were growing with an increase of the growth time. After August 24, the growth process slowed down, which corresponds to the early growing stage. The difference between N-fertilized and control plants (CK) was extremely significant (N2 and CK – $P < 0.01$; N3 and CK – $P < 0.05$). Finally, the differences in the crown diameter among N-treated plants were not significant; average plant crown diameters were between 27.0 and 28.2 cm, which increased by more than 2 times compared with the initial growth stage.

Leaf area indices after N base fertilizer treatments increased in accordance with growth time, but gradually slowed down after 24th. At the initial growth stage, the differences were extremely significant ($P < 0.01$), then differences gradually disappeared, and finally there was no significant difference. The leaf area index for N1 was the highest (134.6), leaf area indices for N1–3 increased by more than 10 times compared with the initial growth stage.

Leaf biomass increased with growing time for N1–3 and gradually slowed down after August 24. At the early stage, the leaf biomass for N2 and N3 were significantly different from CK and N1 ($P < 0.01$). Then differences dropped down and finally disappeared. The N1 leaf biomass was the highest – 74.9 g/m^{-2}, N1–3 increased the leaf biomass by nearly 10 times compared with the initial growth stage.

P base fertilizers. The crown diameter after all P base fertilizer treatments increased with growing time, and then gradually slowed down after August 24th. At the early stage, the difference between crown diameters of CK and P1 and P2 was extremely significant. The average crown diameter for each treatment was between 24.8 and 27.0 cm, which was more than 2.5 times higher compared with the initial growth stage.

The leaf area index of all P base fertilizer treatments gradually slowed down after August 24. At the early stage, the differences between P1, P2 and P3 treatments and CK, P2 and P3 were extremely significant. Then the significance between treatments changed continuously. The leaf area index for P2 was significantly greater than CK, and extremely significantly greater than P3, but not considerably differed from P1. The leaf area index for P 1–3 increased by at least 10 times compared with the initial growth stage.

Leaf biomass of P 1–3 increased obviously with increasing growth time and gradually slowed down after August 24th. In the early stage of growth, leaf biomasses for P1, P2 and P3 were significantly larger than that for CK. During the growth process, the significance of distinction between P 1–3 changed continuously. Finally, the leaf biomass after P2 treatment was significantly larger than for CK and P3, but not significantly differed from P1.

The leaf biomass for each treatment was between 48.3 and 80.9 g m^{-2}, which was about 10 times higher compared with the early stage of growth.

K base fertilizer. The crown diameter for K1–3 increased with growing time, but gradually slowed down after August 24. There were no significant differences between K1–3 parameters during the experiment period. The average crown diameter was between 25.0 and 28.1 cm, with an increase of more than 2.5 times compared with the initial growth stage.

The leaf area index for K1–3 increased obviously with an increase of growth time, and gradually slowed down after August 24th. At the early stage of growth, an essential difference between K2 and CK, K3 and CK, K1 and other groups was detected. The leaf area indexes were between 3.94 and 4.18, which was about 10 times higher than at the early growth stage.

Leaf biomass increased significantly with growing time for K1–3 and gradually slowed down after August 24th. At the early stage of growth, differences between the parameters of K3 and CK, K3 and K1, K2 and K1 were extremely significant. Finally, no considerable distinctions between K1–3 parameters were detected. Leaf biomass after each treatment was between 52.9 and 61.2 g m^{-2}, which was more than 10 times higher than at the early growth stage.

Trend analysis of NPK base fertilizer effects on TKS yield and its component factors

When processing N1–3, P1–3 and K1–3, there were no significant differences between the biomass of leaves, roots, rubber content, sugars or rubber yield of the material collected in the corresponding areas of the field.

N base fertilizer. The N base fertilizer significantly affected parameters of TKS leaf biomass (F = 5.07, $P = 0.044$); when the amount of the N base fertilizer increased from 0 to 107.2 g m^{-2}, the leaf biomass amount changed from 54.5 to 57.0 g m^{-2}, then to 52.9 g m^{-2}. N1 treatment resulted in the highest leaf biomass, reaching 74.89 g m^{-2}, which was about 40% higher than CK (F = 11.90, $P = 0.014$).

N base fertilizer application significantly affected parameters of TKS root biomass (F = 31.24, $P < 0.001$); when the amount of the N base fertilizer increased from 0 to 107.2 g m^{-2}, the root biomass increased from 82.7 to 124.9 g m^{-2}. N3 treatment led to the highest root biomass, reaching 124.9 g m^{-2}, which was about 50% higher than CK (F = 69.20, $P = 0.001$).

The N base fertilizer had a very significant effect on TKS rubber content (F = 301.17, $P = 0.001$); when the N base fertilizer increased from 0 to 107.2 g m^{-2}, the rubber content increased from 5.07% to 6.07%. N3 treatment showed the highest rubber content, reaching 6.07%, which was about 20% higher than CK (F = 660.41, $P = 0.001$).

The N base fertilizer had a significant effect on the TKS total sugar content (F = 8.40, $P = 0.014$); when the N base fertilizer increased from 0 to 107.2 g m^{-2}, the total sugar content changed from 46.8% to 45.0%. Only the difference between N2 and CK was extremely significant. Among the four treatments, the highest total sugar content had the CK group (F = 21.68, $P = 0.004$) (Fig. 1, D).

The N base fertilizer had a very significant effect on TKS rubber yield (F = 70.71, $P = 0.001$). When the N base fertilizer increased from 0 to 107.2 g m^{-2}, the rubber yield increased from 4.19 g m^{-2} to 7.58 g m^{-2}. N3 treatment resulted in the highest rubber yield, reaching 7.58 g m^{-2}, about 80% higher than CK (F = 166.06, $P = 0.001$) (Fig. 1, E).

The N base fertilizer had a very significant effect on the TKS total sugar yield (F = 27.33, $P = 0.001$). When the N base fertilizer increased from 0 to 107.2 g m^{-2}, the total sugar yield increased from 38.7 g m^{-2} up to 56.2 g m^{-2}. N3 treatment resulted in the highest total sugar yield, reaching 56.23 g m^{-2}, which was about 40% higher than the CK (F = 65.53, $P = 0.001$) (Fig. 1, F).

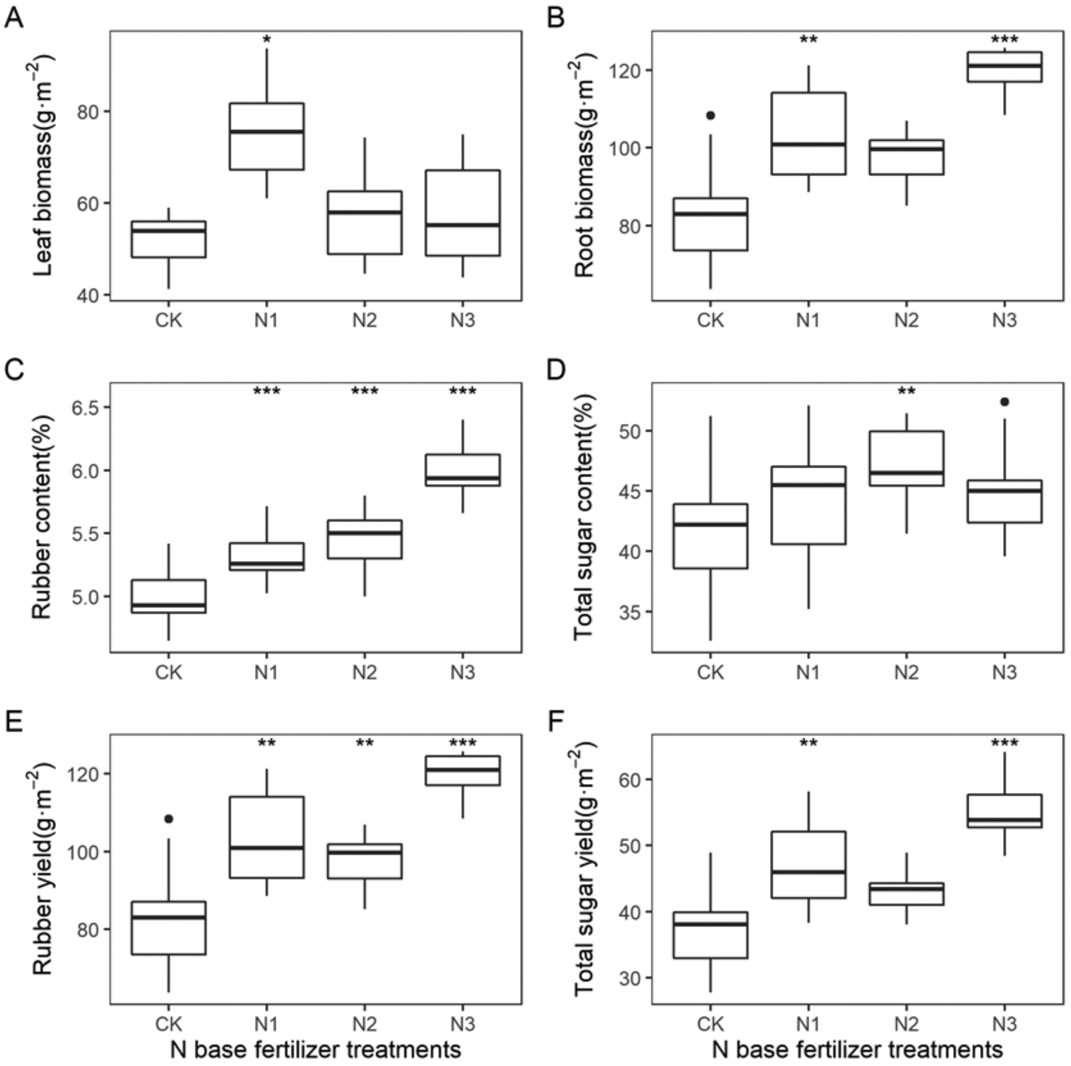

Fig. 1. **Effects of nitrogen base fertilizers on leaf biomass, root biomass, rubber concentration, sugar concentration, rubber yield, and sugar yield of *Taraxacum kok-saghyz* Rodin (TKS)**

Рис. 1. **Влияние азотных удобрений на биомассу листьев, биомассу корней, концентрацию каучука, концентрацию сахара, выход каучука и выход сахара у кок-сагыза (*Taraxacum kok-saghyz* Rodin)**

P base fertilizer. The effect of the P base fertilizer on TKS leaf dry weight was significant (F = 8.31, P = 0.015). When the P base fertilizer increased from 0 to 10.5 g·m^{-2}, the leaf biomass changed from 61.2 g m^{-2} to 48.3 g m^{-2}. P2 treatment led to the highest leaf dry weight, reaching 80.88 g m^{-2}, more than 30% compared with CK (F = 9.12, P = 0.023) (Fig. 2, A).

The effect of the P base fertilizer on the TKS root biomass was extremely significant (F = 23.16, P = 0.001). When the P base fertilizer increased from 0 to 10.5 g m^{-2}, the root biomass changed from 54.5 to 82.7 g m^{-2}, then to 108.7 g m^{-2}. P1 treatment resulted in the highest root biomass, reaching 117.40 g m^{-2}, which was about 35% higher than CK (F = 63.18, P = 0.001) (Fig. 2, B).

The effect of the P base fertilizer on the rubber content of TKS was extremely significant (F = 65.08, P = 0.001). When the P base fertilizer increased from 0 to 10.5 g m^{-2}, the rubber content increased from 5.07% to 5.97%. Among the four treatments, the highest rubber content was reached with P3 treatment, amounting to 5.97%, which was about 20% higher than CK (F = 139.27, P = 0.001) (Fig. 2, C).

The P base fertilizer had a significant effect on the TKS total sugar content (F = 7.36, P = 0.020). When the P base fertilizer increased from 0 to 10.5 g m^{-2}, the total sugar content increased from 46.8% to 52.7%. The highest rubber content was registered for P3 group, reaching 48.43%, which was about 4% higher than CK (F = 20.70, P = 0,004) (Fig. 2, D). The effect of the P base fertilizer on TKS rubber yield was extremely significant (F = 35.49, P = 0.001). When the P base fertilizer increased from 0 to 10.5 g m^{-2}, the rubber yield increased from 4.2 g m^{-2} to 6.5 g m^{-2}. P2 and P3 resulted in the highest rubber yield, reaching 5.95–6.49 g m^{-2}, which was higher than CK by around 50% (F = 12.29, P = 0.013; F = 26.71, P = 0.002) (Fig. 2, E).

The P base fertilizer had a very significant effect on the TKS total sugar yield (F = 23.87, P = 0.001). When P base fertilizer application increased from 0 to 10.5 g m^{-2}, the total sugar yield increased from 38.7 g m^{-2} up to 52.6 g m^{-2}. P1 and P3 demonstrated the highest rubber yield, reaching 52.65–54.72 g m^{-2}, that was about 40% higher than CK (F = 59.80, P = 0.001; F = 7.93, P = 0.031) (Fig. 2, F).

K base fertilizer. Application of K fertilizers caused a stable decline in TKS leaf dry weight.

The K base fertilizer had a very significant effect on TKS root biomass (F = 134.41, P = 0.001). When the K base fertilizer increased from 0 to 35.3 g m^{-2}, the root biomass increased from 82.7 g m^{-2} to 142 g m^{-2}. K3 treatment caused the highest root biomass, reaching 142 g·m^{-2}, which was more than 70% higher than CK (F = 10.95, P = 0.016; F = 391.01, P = 0.001) (Fig. 3, B).

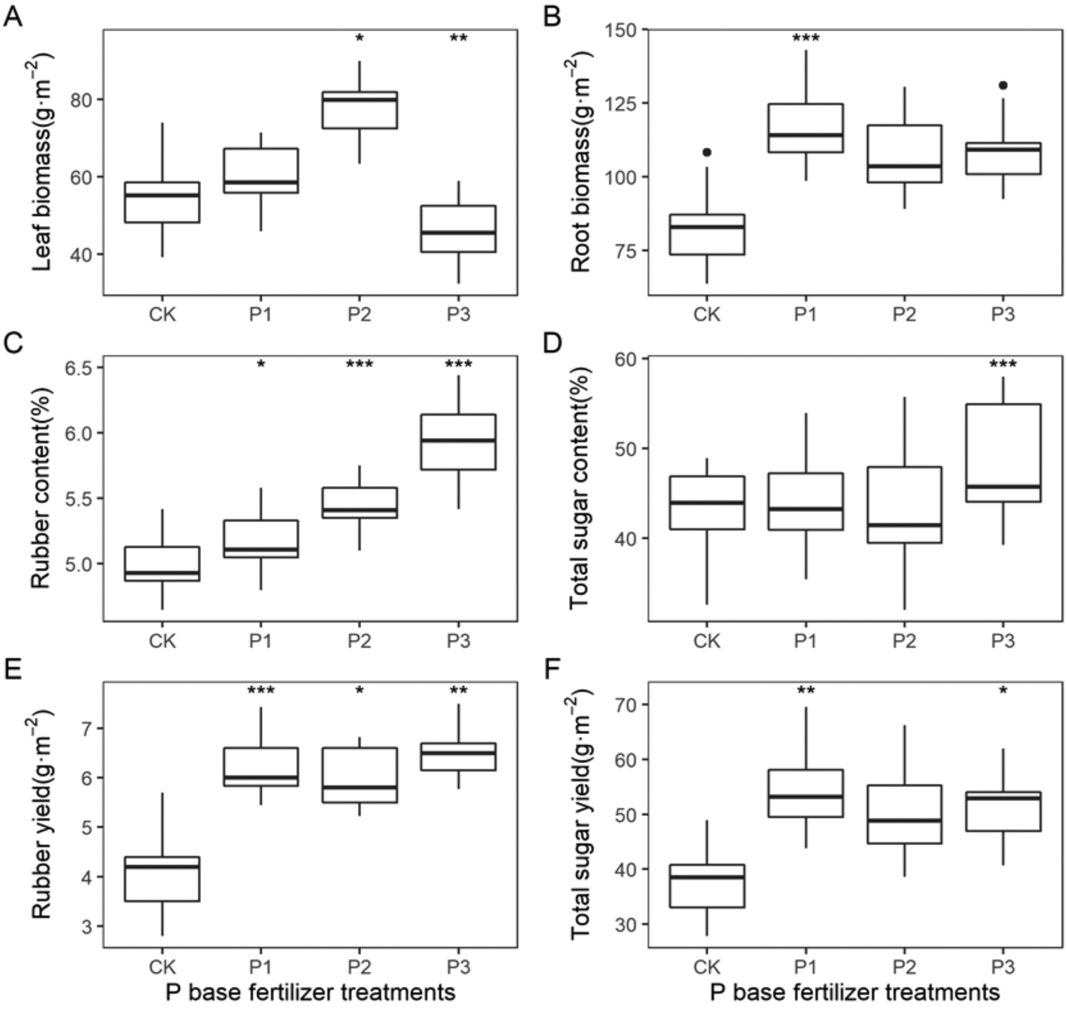

Fig. 2. Effects of phosphorus base fertilizers on leaf biomass, root biomass, rubber concentration, sugar content, rubber yield, and sugar yield of *Taraxacum kok-saghyz* Rodin (TKS)

Рис. 2. Влияние удобрения на основе фосфора на биомассу листьев, биомассу корней, концентрацию каучука, содержание сахара, выход каучука и выход сахара у кок-сагыза (*Taraxacum kok-saghyz* Rodin)

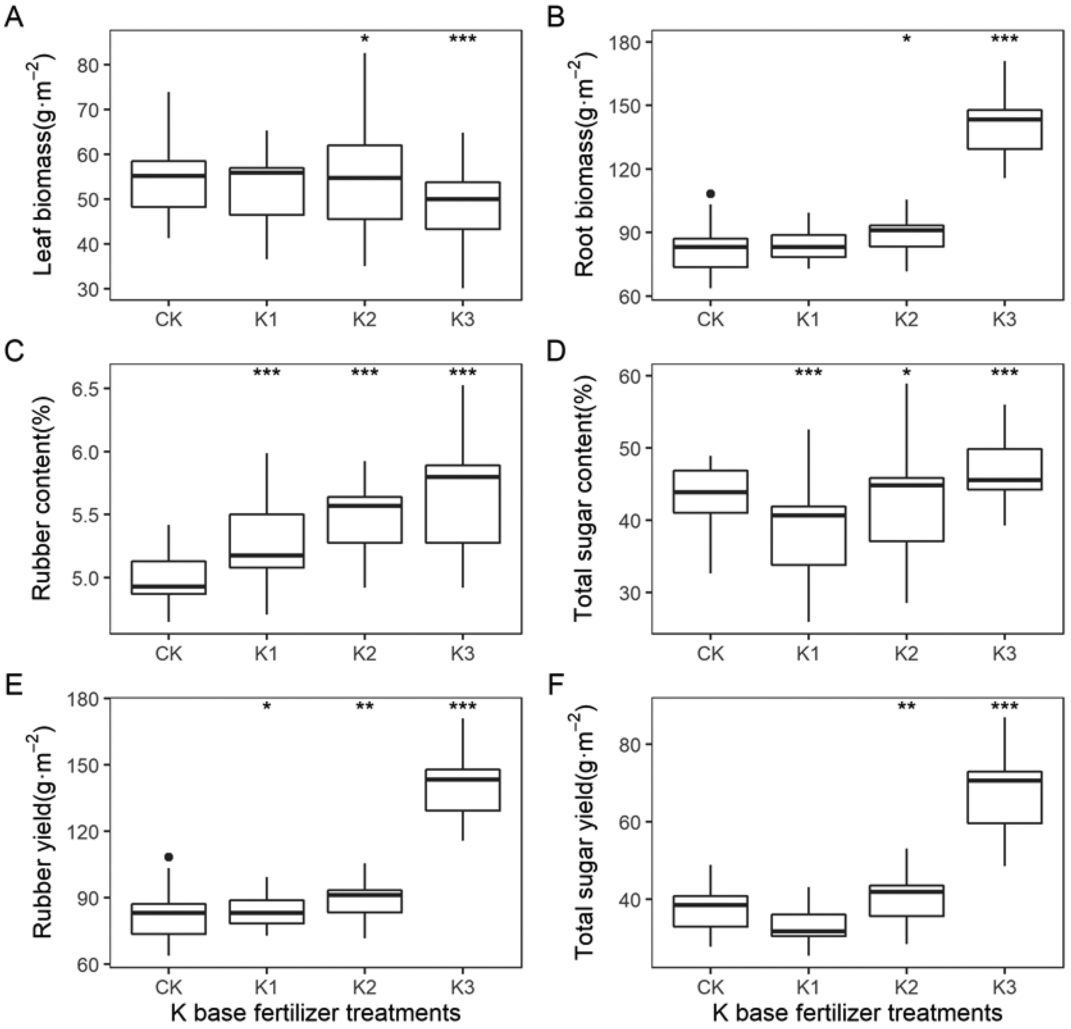

Fig. 3. **Effects of potassium base fertilizers on leaf biomass, root biomass, rubber content, sugar content, rubber yield, and sugar yield of *Taraxacum kok-saghyz* Rodin (TKS)**

Рис. 3. **Влияние удобрения на основе калия на биомассу листьев, биомассу корней, содержание каучука, содержание сахара, выход каучука и выход сахара у кок-сагыза (*Taraxacum kok-saghyz* Rodin)**

The K base fertilizer had a very significant effect on TKS rubber content (F = 214.25, *P* = 0.001). When the K base fertilizer increased from 0 to 35.3 g m^{-2}, the rubber content increased from 5.07% to 5.84%. K3 treatment resulted in the highest rubber content, reaching 5.84%, which was about 16% higher than CK (F = 351.31, *P* = 0.001) (Fig. 3, C).

The K base fertilizer had a very significant effect on the TKS total sugar content (F = 195.73, *P* = 0.001). When the K base fertilizer increased from 0 to 35.3 g m^{-2}, the total sugar content increased from 46.8% to 49.3%. K3 treatment led to the highest total sugar content, reaching 49.33%, which was about 5% higher than CK (F = 309.89, *P* = 0.001) (Fig. 3, D).

The K base fertilizer had a very significant effect on the TKS rubber yield (F = 190.52, *P* = 0.001). When the K base fertilizer increased from 0 to 35.3 g m^{-2}, the rubber yield increased from 4.19 g m^{-2} to 8.30 g m^{-2}. K3 treatment resulted in the highest rubber yield, reaching 8.30 g m^{-2}, about 1 time higher compared with CK (F = 540.14, *P* = 0.001) (Fig. 3, E). The K base fertilizer had a very significant effect on the TKS total sugar yield (F = 200.25, *P* = 0.001). When the K base fertilizer increased from 0 to 35.3 g m^{-2}, the total sugar yield increased from 38.7 g m^{-2} to 69.5 g m^{-2}. K3 treatment led to the highest total sugar yield, reaching 69.9 g m^{-2}, which was about 80% higher than CK (F = 582.147, P = 0.001) (Fig. 3, F).

Discussion

This study shows that under local soil conditions, appropriate N and P fertilization can promote rising of TKS leaf biomass, while the K fertilizer can reduce it. They can effectively increase TKS rubber yield and total sugar yield, which means that they are necessary for an increase of TKS yield biomass. The promoting effect of base fertilizers on TKS yield is consistent with many previous studies (Luo, 1951; Stepanov et al., 1952), while the trend analysis of rubber yield and total sugar yield in TSK biomass has not attracted attention to before. Studying the total sugar yield can improve the economic benefits of TKS and identify the suitable amount of fertilizers to maximize TKS output, which does not contradict the data we obtained (Guang, 2021). This study shows that both N3 and K3, P1 or P3 treatments can maximize the rubber yield and total sugar yield of TKS. Certainly, the use of fertilizers depends on the local conditions of the crop reproduction region (IPNI, 2012), which is also confirmed by our results. We estimated the yield response model through the response curves, which could be used to determine the optimal amount of fertilization and lay the foundation for further research. There are many reports proving the effectiveness of the use of combined fertilizers to increase economically significant indicators (Wang et al., 2002; Yue, 2008; Cerrato, Blackmer, 1990; Bélanger et al., 2000; Valkama et al., 2011; Liu, 2012; Liang, 2017). These models are mainly based on Mistcherlich's law of diminishing returns, that is, as the crop yield gradually approaches the maximum value, the fertilizer effect gradually decreases (Ferreira et al., 2017). In this study, we found that the response of rubber yield and total sugar yield to N and P base fertilizer treatment and the response of total sugar yield to the K base fertilizer are significantly in a linear trend. And the response of rubber yield to K base fertilization relatively fits a quadratic polynomial model. The results indicate that in the range of applied fertilizer amount, the rubber yield and total sugar yield have been increasing. That is, in order to determine the optimal amount of fertilizers needed to increase the economic value of TKS, it is necessary to continue studying this problem.

A crop's nutrient requirements are affected by climate, soil, varieties, etc., which is clearly confirmed by our experiment.

The use of fertilizers makes it possible to reduce costs in the production of economically important crops (Baligar, Bennett, 1986). The base fertilizer satisfies the nutritional needs of crops throughout the growing season, especially in the early stages of development. Top-dressing fertilization is necessary during the critical period of plant development. Therefore, the efficiency of using only the base fertilizer will be relatively low. In the current experiment we studied only the impact of base fertilizers on the parameters of TKS final yield.

Conclusion

Kok-saghyz responds positively to the application of mineral fertilizers. Under the conditions of the experimental station in Harbin we recommended the following amount of base fertilizers for kok-saghyz production: 107.2 g m^{-2} of urea, 43.4 g m^{-2} of calcium superphosphate, and 10.5 g m^{-2} of potassium chloride. To optimize the use of fertilizers and reduce costs in the production of TCS, it is necessary to study the key periods of crop growth and their corresponding nutritional requirements. This will reduce the amount of the base fertilizer and optimize the fertilizer's application time, i. e., increase the efficiency of fertilizer usage.

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