Ability of black soil supplying potassium and effect of potassic fertilizer on soybean

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Abstract

The black land is distributed in a narrow area from south to north in northeast of China Nine soil samples with high, middle and low fertility were collected in the field of south, north and middle area. These samples were analyzed in laboratory, and pot experiment was performed mainly in Harbin. The results showed that Black soil has high potential of providing potassium, the concentration of available potassium in the soil was 121~212 mg kg^{-1} in different fertility soils and different place; the slowly available potassium was 656-1256 mg kg^{-1}, all of which are of middle or high level. The content of potassium is sufficient for soybean growth under normal production conditions and there no effect on increasing yield. Under drought condition, the potassium increased yield by 15.6%. Under the condition of serious plant diseases and insect pests, the potassium increased the yield by 10.5%-22.6% under soybean following other crops and by 11.6%-23.8% under continuous cropping. Increasing the N and P application singly for high yield, there would be no increasing effect in yield. But if the N, P and K were increased at the same time, the yield would be increased by 8.6%.

Keywords: black soil, providing potassium, soybean, potassium fertilizer

Introduction

With the ceaseless elevation of agriculture productivity, the reports on potassium application could increase the soybean yield in blacksoil is increasing during the past few years (Guangwu, 1995; Yuying, 1993; Xiuqing, 1995) and at the same time more and more potassium fertilizer was applied continuously. Potassium is not the life-structure matter but the growth regulator for soybean. In the blacksoil region, where has more abundant potassium than other soil region, the reason which impact the absorption of potassium by soybean and efficiency of potassium could be found in the following aspects: first of all is that the available potassium is not enough for the lowest needs of soybean production, the second is the effect of drought, disease and pest injure on the absorption of potassium by soybean. There are fewer reports on these aspects. This experiment was conducted by analysis in laboratory, pot and field experiments. The potential potassium of blacksoil and the mechanism of increasing soybean production were studied systematically, which could provide the theoretical foundation for K application of soybean in blacksoil region.

Materials and Methods

Materials

The samples were taken from Gongzhuling as the South region, Harbin as central section and Hailun as North region. The samples were collected in the fields with high, middle or low fertility, which could represent the feature of the region they belonged to, for analyzing in lab and pot test. Table 1 shows the elementary properties of the soils.

Table 1 The primary properties of the tested soil.

Spot	No.	Fertility	Organic C (g kg-1)	Total N ($g\ kg^{-1}$)	Available N ($mg\ kg^{-1}$)	Total P ($g\ kg^{-1}$)	Available P ($mg\ kg^{-1}$)	Total K ($g\ kg^{-1}$)	Slow release K ($mg\ kg^{-1}$)	Available K ($mg\ kg^{-1}$)	pH
Hailun	1	High	29.12	2.54	219.5	1.80	108.0	25.2	1265	212	6.84
	2	Mid	26.68	2.39	199.5	1.42	71.0	26.9	1105	198	7.14
	3	Low	21.23	1.06	132.1	1.28	32.6	24.3	908	167	7.00
Harbin	4	High	25.00	1.69	135.8	1.45	69.4	24.8	1136	199	7.15
	5	Mid	17.05	1.41	118.5	1.52	45.6	25.1	867	171	7.20
	6	Low	11.60	1.00	101.3	1.46	38.4	26.2	725	142	7.15
Gongzhuling	7	High	16.76	1.58	115.7	1.19	63.5	24.7	1014	195	7.35
	8	Mid	12.65	1.34	97.7	0.97	57.8	24.8	821	164	7.40
	9	Low	9.24	0.75	73.6	1.86	43.1	24.0	656	121	7.25

Method for measuring some nature of soil

Total potassium in soil was determined by soda alkali fusion. The slow release K was extracted with 1 N hot nitric acid and the available K with 1 N ammonium acetate. The total N was determined by alkaline hydrolytic pervasive absorption method. The total P by caustic soda alkali fusion; available P by baking soda method. The pH was determined by pH-2 pH meter. The ratio of water and soil was 1:1.

Pot test

Efficiency of potassic fertilizer

The 9 samples of blacksoil with high, medium and low fertility from 3 spots were potted in proper order. The samples were taken at 20 cm depth and 2 kg weight each layer. Two treatments are: potassium (K_2O) application at 0.15 g kg^{-1} soil and no-application of potassium. All treatments were applied nitrogen at 0.04 g kg^{-1} soil and phosphorus at 0.02 g kg^{-1} soil.

Drought-resisting effect of potassic fertilizer

The nine samples were potted and applied with N, P and K fertilizer as in test (1). Four treatment were set up: without potassium applied, normal moisture; without potassium applied, drought; potassium applied, normal moisture; potassium applied, drought. The field moisture capacity of Hailun blacksoil was 65%. And the normal moisture was controlled around at 45% of Hailun blacksoil. The soil moisture of drought treatment was controlled at 60% of normal moisture before July 10 and 70% of normal moisture after July 10.

Effect of potassic fertilizer with high nitrogen and phosphorus

The nine samples were potted and applied with K fertilizer as in test (1). Four treatment were set up: The nitrogen and phosphorus were applied as treatment (1), no potassium applied. The nitrogen and phosphorus were applied as treatment (1), the potassium was applied. The nitrogen was applied at 0.06 g kg^{-1} soil and the phosphorus (P_2O_5) 0.03 g kg^{-1} soil, no potassium was applied. Nitrogen was applied at 0.06 g kg^{-1} soil and the phosphorus (P_2O_5) 0.03 g kg^{-1} soil, the potassium was applied. All pot tests above had 5 replications and were arranged randomly. The nitrogen fertilizer was commercial urea in which the nitrogen content was 46%. The phosphatic fertilizer was diammonium orthophosphate with 19.8% phosphorus content and 18% nitrogen. The potassic fertilizer was potassium sulfate with 38% potassium content.

Field test

Field micro-plot test

In order to examine the sensitivity of soybean on continuous cropping or with one-year halt to potassium element, we set micro-plot test in the fields of rotation, continuous cropping and one-year halt of soybean separately. The micro-plot was 0.7 m wide and 1.5 m long (1.05 m^2). Seven treatments were set up: (1) Control (2) 18.7 kg potassium hm^{-2}. (3) 37.3 kg potassium hm^{-2}. (4) 56.0 kg potassium hm^{-2}. (5) 74.7 kg potassium hm^{-2}. (6) 93.3 kg potassium hm^{-2}. (7) 112.0 kg potassium hm^{-2}. All seven treatments above were applied nitrogen at 26.3 kg hm^{-2} and phosphorus at 30.1 kg hm^{-2}.

Field tests

Seven treatments were set up in the field of rotation, continuous cropping and one-year halt of soybean separately: (1) Control. (2) 37.4 kg potassium hm^{-2} (3) 74.7 kg potassium hm^{-2}. (4) 112.1 kg potassium hm^{-2}. (5) 149.4 kg potassium hm^{-2}. (6) 186.8 kg potassium hm^{-2}. (7) 224.0 kg potassium hm^{-2}. All the 7 treatments were applied diammonium orthophosphate at 150 kg hm^{-2}.

Results and Discussion

Ability of black soil supplying potassium and effect of potassic fertilizer

We collected the 9 samples with high, middle and low fertility from the South, the North and the Medium region, which could represent the narrow and long blacksoil area. The effect of potassium on soybean was examined in the same fertility and moisture conditions. The results were shown as Figure 1 and Figure 2. Figure 1 showed that, with potassium applied, the yields between lamella soils with high, middle and low fertility in South region and the medium and thick blacksoil with high, middle and low fertility in North region has no significant difference, which was tested by least significant difference (LSR) method. The other 9 spots without potassium application also showed no significant difference on yields. This indicated that in the condition of being applied enough nitrogen, phosphorus and water, the 9 spots with potassium application or not has no difference on yield, which meaned that spots had no effect on yield. There is no significant difference between spots with potassium applied and without potassium applied. This indicated sufficiently that available potassium of blacksoil could meet the needs of soybean growing in normal condition. Blacksoil is one of the soils which has the most sufficient ability for applying potassium (Xiuqing, 1995) potassium in blacksoil was 121-212 mg kg^{-1} soil, which all was higher than the high level (high level 120 mg kg^{-1} soil middle level 60-120 mg kg^{-1} soil low level 60 mg kg^{-1} soil (Jianchang, 1988) that was generally accepted by researchers. The slow released potassium content was 656-1256 mg kg^{-1} soil, which was higher than the high level (high level 700 mg kg^{-1} soil middle level 300-700 mg kg^{-1} soil low level 300 mg kg^{-1}

soil (Jianchang, 1988). Soybean is a crop of low yield, The average unit area yield for many years in blacksoil region was 1,500-1,600 kg hm^{-2} the requirement for potassium is less than maize, wheat and sugar beet. So potassium fertilizer has little effect on soybean yield, this showed that blacksoil could provide soybean with sufficient potassium for normal growth.

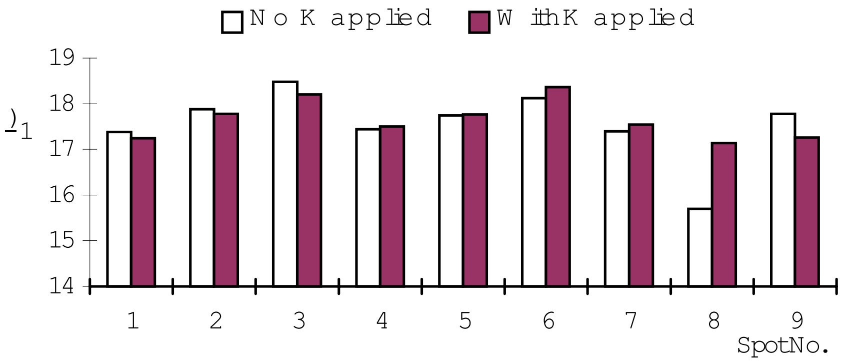

Figure 1 Effect of K fertilizer on soybean.

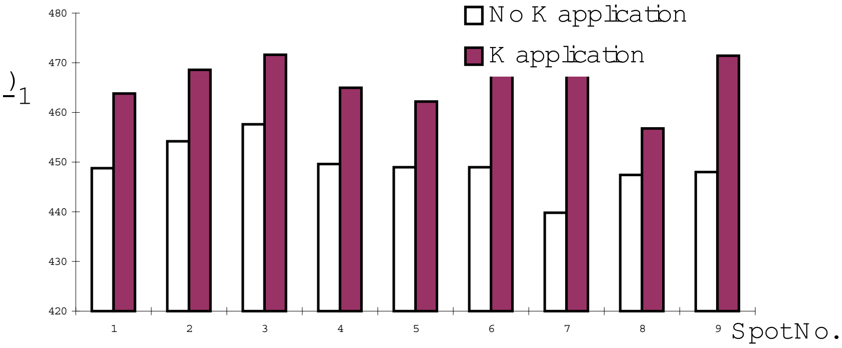

Figure 2 Effect of K application on nutrient body.

Figure 1 showed that without potassium applied treatments had little effect on soybean yield at neither No. 1 spot with high available potassium content nor No. 9 spot with low available potassium content. The weight of seeds did not reached the significant difference, which certified once again that the available potassium content of blacksoil was higher than the available potassium in soil which needed by soybean growing normally. Figure 2 showed that, compare with the control, the total weight of soybean plant with potassium-applied treatment has been significant increased. This is possibly related to biology characters of soybean itself: one of them is physiological phenomenon those soybeans absorb potassium extravagantly which occurred when soil applying potassium at a certain degree. The other one is that the vegetative growth must proceed with reproductive growth in phase, for the simple overgrowth of plant was not the signal of high yield.

Effect of potassium fertilizer on drought resistance of soybean

Drought was the main factor, which restricts the soybean production. Drought year appear frequently. Test showed that: In drought conditions, which was applied water less than normal by 1/3, all the 9 soil samples from 3 spots harvest low yield. The yield of soybean grain without potassium applied decreased by 16.48%, the weight of soybean vegetative plant decreased by 16.40%, reached the extreme significant difference (P>0.01). The yield of soybean grain with potassium applied decreased by 3.4% with no significant difference. The total weight of soybean vegetative plants decrease by 11.60%. Figure 3 and Figure 4 showed that there is a significant effect of potassium application in drought condition. The grain production increased by 15.65%, reached the extreme significant difference (P>0.01), the weight of soybean vegetative plants decreased by 9.74% (P>0.01). Drought resistance could be strengthened by increasing potassium application, for the potassium ions had the colloid character that could accommodate the bioplasm and keep the colloid a certain divergence, degree of hydration and treacliness and so on. Potassium ions could increase the hydration of bioplasm and cacium ions could prompt the bioplasm concentrating and lower the permeability of cell. Existing simultaneously, they keep the colloid a certain divergence, viscidity and permeability. So the water could get into the cell favorably, strengthened the moisture-retaining power of cell, increased the drought resistance of soybean. Potassium ions could influence the stomatic movement, whereby regulated the transpiration (Shufan, 1993).

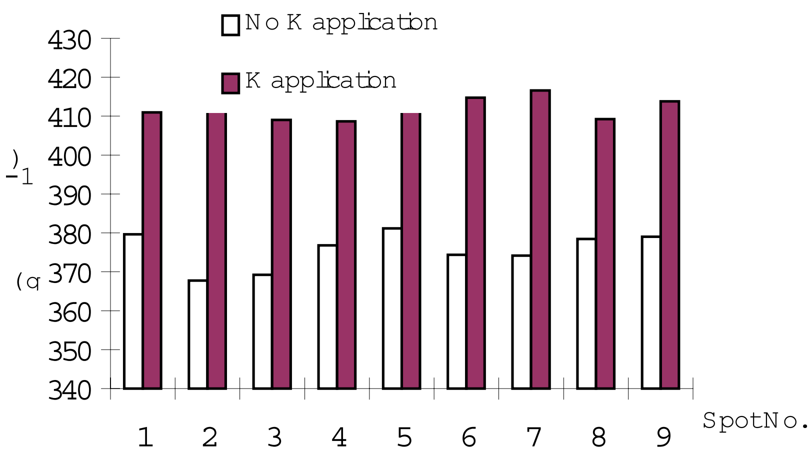

Figure 3 Effect of K application on the plant weight in drought condition.

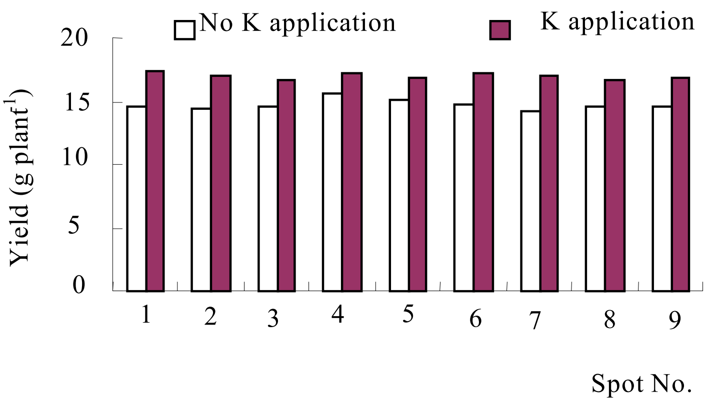

Figure 4 Effect of K application in drought condition on yield.

Effect of potassium fertilizer in high N, P condition

The nutrition element needed by soybean growth must be applied in proper rate. The nitrogen and phosphorus application increased, the potassium application must be raised suitably too, and then the yield could be increased. Figure 5 and Figure 6 showed the effect of potassium fertilizer that was 1.5 times more than normal. When nitrogen and phosphorus applied separately, the high-level nitrogen and phosphorus got less production than normal level. There is not significant difference in yield and weight of soybean vegetative body. Potassium application has been increased with high-level nitrogen and phosphorus, the grain production increased by 8.67%, the difference got significantly (Figure 5), but the vegetative body not. Thinking from the aspect of nutrition and physiology, for more production, nitrogen and phosphorus must be applied together with potassium. Because potassium was a activator for many zymes, which could promote the metabolization and synthesis of carbohydrate and then promote the synthesis of soils. Potassium had evident influence on nitrogen metabolization and protein synthesis, because potassium accelerated metabolization of carbohydrate, the organic acid was produced for accepting NH_4^+, which was available to forming amino-acid and accelerating the protein synthesis.

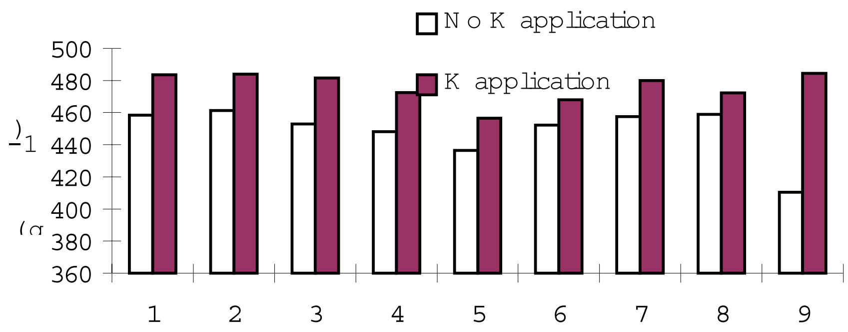

Figure 5 Effect of K in high N and P application on nutrient body.

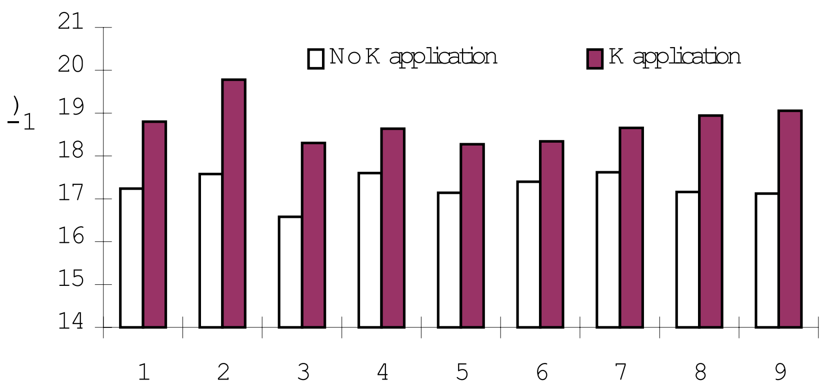

Figure 6 Effect of K in high N and P application on yield.

The feature of demanding potassium for continuous or one year suspend cropping of soybean and fertilization practices

Results of micro-spots test

Figure 7 showed that potassium application had significant effect on the yield of continuous or one-year suspend cropping of soybean. The yield of one year suspend cropping of soybean had linear relation to potassium application within 3.8 g m^{-2}. The yield of continuous cropping of soybean did also within 12 g potassium m^{-2}.

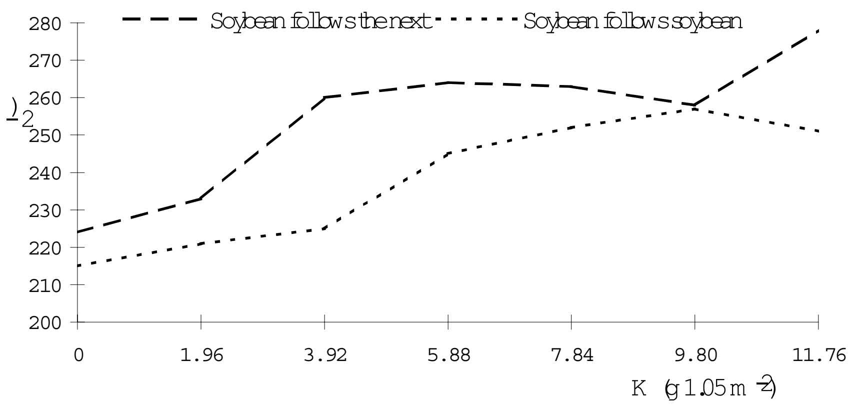

Figure 7 Influence of variable K application on the yield of soybean follows soybean or follows the next.

Results of field test

The result of potassium test on soybean one year suspend cropping was shown in Figure 8. From which we could see that the potassium application with nitrogen and phosphorus application on soybean one year suspend cropping increased the yield remarkable by 10.58, 34.13. There were two characters comparing the potassium application with nitrogen and phosphorus application: One was the yield increase with potassium application increase, that is the yield and the potassium application had linear relation within 224.1 kg potassium hm^{-2}, and the yield change with the nitrogen and phosphorus application in parabola relation. The second was the yield increase with potassium application in a small extent by 10.58, however, in the first range of nitrogen and phosphorus experiments, the yield increased by 17% more from N and P application and only 10.58% from K (Guangwu, 1995). Thus it can be seen that in the aspect of fertilizer variety the nitrogen and phosphorus were needed first of all, secondly the potassium.

The significance test has been conducted for spot yield of potassium application on soybean one year suspend cropping. The result showed that the yield of all treatments with potassium was more remarkable than that of without potassium application. The yield increasing was not remarkable within 74.7 kg potassium hm^{-2} 186.8 kg potassium hm^{-2}. The yield increasing reached significant difference with potassium application by 37.4 kg hm^{-2} and 224.1 kg hm^{-2}.

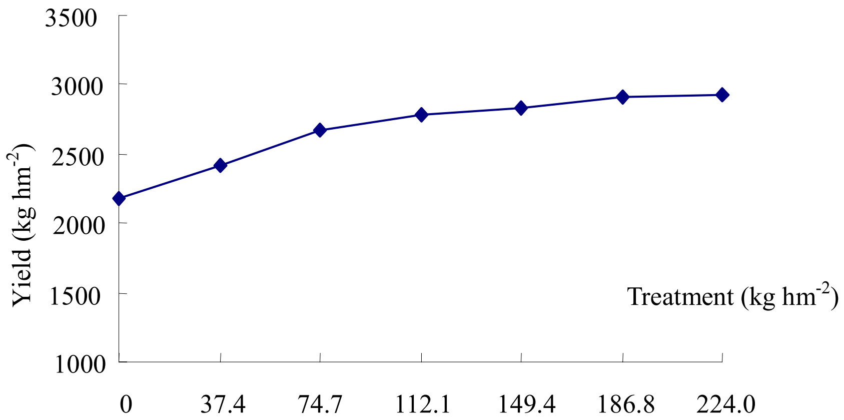

Figure 8 Yield of soybean follows the next with K application.

The yield of soybean on continuous cropping with potassium application was shown in Figure 9. The yield gradually increased as the potassium application increased. The yield would increase little as applying potassium more than 149 kg hm^{-2}. And the soybean on one year-suspend did the same as applying potassium more than 74.7 kg hm^{-2}. These results suggested that the potassium needed by continuous cropping of soybean were more than one year-suspend of soybean. The results of significance test showed that the yield of all the treatments with potassium application was significant comparing with the CK. The increased yields reached significant difference with the potassium application by 37.4 kg hm^{-2}, 74.7 kg hm^{-2} and 24.1 kg hm^{-2}. Because the diseases and insect pests was the main factor leading to decreased production on continuous cropping of or one year-suspend of soybean. Potassium could strengthen the disease resistance of soybean and accelerate the synthesis of root and stem cellulose. When enough potassium being applied, the cellulose in soybean stem and leaf increased, which would accelerate the growth of cauline bundle, then the collenchyma cell being thickened, the intensity of root and stem enhanced, the plant growing strongly and the resistance for plant diseases and insect pests also be strengthened.

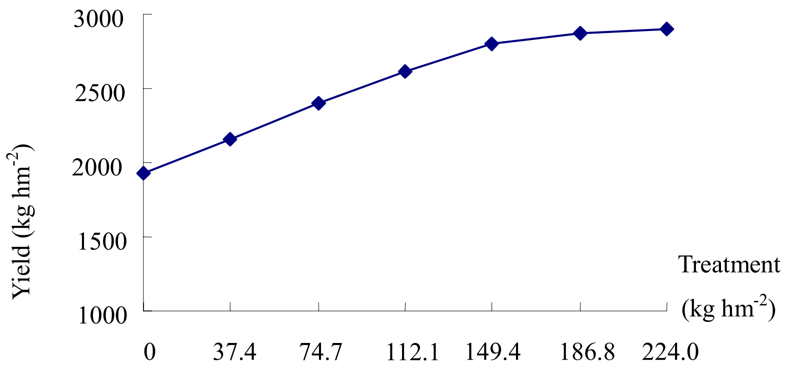

Figure 9 Yields of soybean follows soybean with K application.

Conclusions

Blacksoil was one kind of fertile soil. There is abundant of available potassium for soybean's normal growth. Increasing potassium on such soil cannot increase the production. During soybean growth, potassium application would has obviously function on controlling yield decrease when the natural calamities occurred such as drought, diseases and insect pests and so on. When increase the nitrogen and phosphorus in order to get high yield of soybean, it is necessary to applied potassium at the same time.

The blacksoil region has abundant potassium in its soil. The content of the available potassium in defferent soil was 121-212 mg kg^{-1} soil, and the slow-released potassium is 656-1256 mg kg^{-1} soil. In normal production conditions, the potassium in blacksoil was sufficient for soybean growth. Testing by least significant difference (LSR) method, the yield of the treatments with potassium application did not increased obviously. Potassium could increase production by 15.6% in condition of drought. When the diseases and insect pests turned seriously, potassium application could increase production obviously, the yield on the one-year–suspend cropping of soybean was increased by 10.5%~22.6%, the continuous cropping of soybean was increased by 11.6%~23.8%. There would have no effect on yield increase with nitrogen and phosphorus application separately, and the yield of soybean with nitrogen, phosphorus and potassium applied together would be increased by 8.6%.

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