The nutrient release kinetics of Polyhalite and its biological effect on tea growth and quality in China

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Abstract

Nutrition of potassium (K) and magnesium (Mg) is crucial for tea (*Camellia Sinensis*) plantation, both in yield and quality components formation. However, the soil in southern China, where most tea trees are planted, can be characterized as low K and Mg supplying capacity as well as low inherent fertility. More than 60% surveyed tea plantation soil were deficient in K and Mg. Thus, fertilization by K and Mg holds potential in promotion of tea yield and quality in tea production. Polyhalite is a natural and combined nutrients fertilizer including K, Mg, Ca and S, which holds some advantages compared with other compound fertilizers, such as low solubility, without Cl toxicity and less labor cost. Its impact on yield has been widely tested in field investigation of maize, potatoes. However, for the consideration of the risk of high Ca, its potential application in tea plantation still needs carefully tested. In this IPI supported project, we investigated the nutrients release of polyhalite in acidic tea plantation soil and its biological effects on tea trees both in pot and field trials. The results confirmed the previous findings that original polyhalite fertilizer has slower nutrient release rate than common sulphate fertilizers. This also caused the nutrient accumulation on the top soil layer, which may reduce the risk of nutrient loss by leaching. Pot experiment showed that application of Polyhalite according to K rate significantly increased the biomass of young shoots by 19~33%, compared with normal fertilizers. The significant effect of Polyhalite is its promotion on tea quality component, amino acid, which is the most important component in green tea taste. Treatments with polyhailte increased the amino acid concentration by 22~26%, significantly higher than

4.5~15% in common fertilizers. Polyhalite also showed increase effect on polyphenol concentration. But the highest polyphenol concentration was in treatment supplying with calcium sulphate. In autumn season, polyhalite treatment also showed higher amino acid and lower polyphenols concentration than NPKMg treatment, despite the N rate. Due to its lowest PP:AA ratio and soil properties, it implied the potential beneficial application of polyhalite in tea gardens to improve green tea quality with Mg deficiency.

Experimetn design

1. Leaching experiment

Totally 7 treatments were tested in this leaching experiment. The standard addition of K and Mg were 100 mg kg^{-1} and 20 mg kg^{-1} respectively, in treatment "K+Mg".

Table 1 The fertilization treatments in the pot and leaching experiment

No.	Code	Explanations
tr1	CK	Control
tr2	K	K addition
tr3	K+Mg	K and Mg addition (zero Ca)
tr4	PolyK	Polyhalite addition as the K in tr3, high Ca input
tr5	PolyMg+K	Polyhalite addition as the Mg in tr3, and K added to the level in tr 3
tr6	PolyMg	Polyhalite addition as the Mg in tr3, half Ca input as in tr4
tr7	K+Mg+Ca	K and Mg as tr3, but medium Ca addition between tr3 and tr 5

The studied soil was packed into a PVC column (60 cm in length and 5 cm in diameter). After specific fertilizer addition, 200 mL distilled water was added periodically to the soil column, and then the downward leachate was sampled. The K, Ca, Mg and S in the leachate was measured by ICP-AEC.

2. Pot experiment

Similar to experiment 1, totally 7 treatments were tested in the pot experiment. The standard addition of K and Mg were 90 kg^{-1} ha^{-1} and 18 kg^{-1} ha^{-1} respectively, in treatment "K+Mg". The N and P were applied by 300 and 90 kg^{-1} ha^{-1} respectively. For tree growth, 20 kg soil was imported to the pot and planted with 4 tea trees (Variety Longjing 43). In spring, the young shoot was plucked for yield calculation and the amino acid and polyphenol in the young shoot was also measured as quality index.

3. Field experiment

To investigate the effect of polyhalite on Mg-deficiency soil, 5 treatments were investigated in the field trial. The main factor was N rate (300 vs 500 kg N ha^{-1}). In each main factor, different fertilizers were tested, including single K without Mg, K plus Mg, foliar Mg application, compound fertilizers Polyhalite and compound fertilizer specially for tree.

Table 2 Field experiment design

Treatment	N1 (300 kg N ha^{-1})	N2 (500 kg N ha^{-1})	Comments
NPK	-	-	-Mg
NPKMg	50 MgO	50 MgO	+Mg
NPKMg+F	20 MgO + $MgSO_4.7H_2O$	20 MgO + $MgSO_4.7H_2O$	+Foliar Mg
Poly	50 MgO	50 MgO	Polyhalite
Compound	50 MgO	50 MgO	Compound

The field trial was started in April, 2017, thus samples were collected in autumn season, due to the low quality in summer.

Results

1. K, Mg, Ca and S releasing from the Polyhalite

Nutrient K, Mg and Ca are essential for the plant development. It was assumed that the nutrient would release slowly than common fertilizers. Compared with K treatment, poly_K treatment showed the 50% less amount K during the leaching of 2000 mL, and 35% less at the end of observation by 5000 mL leaching (Fig. 1). This effect could also be found in other treatments using polyhalite. From the dynamic of leaching, all treatments using polyhalite fertilizers had a slow release of nutrient elements of K (Fig. 2).

However, the effect is different for Mg (Fig. 2) if compared with K. PolyMg and PolyMg+K treatment both showed higher Mg collection than treatment K+Mg. It may be due to the adsorption by the soil colloid. Ion Mg^{2+} has higher charge and stronger affinity than K^+. This could also explain the phenomena in Ca leaching. In treatments

of polyK, poly_Ca and K+Mg+K with three different Ca addition levels, there was no significant difference in Ca leaching collection. But the treatments without Ca addition (K, K+Mg and CK) showed significant less Ca leaching (Fig. 1 and 2).

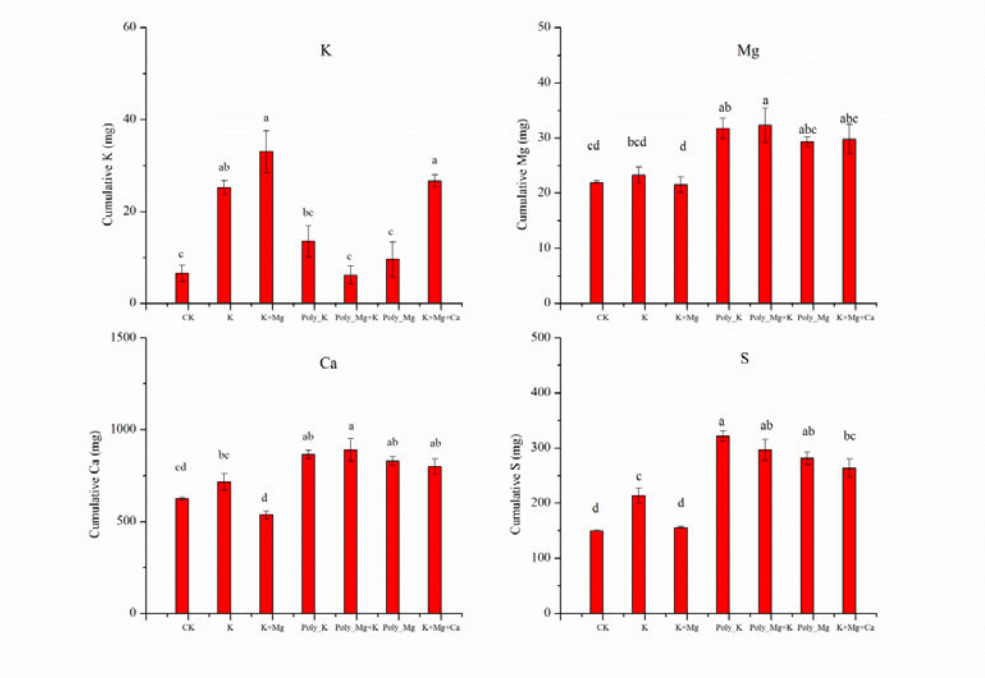

Figure 1 Cumulative element during the leaching

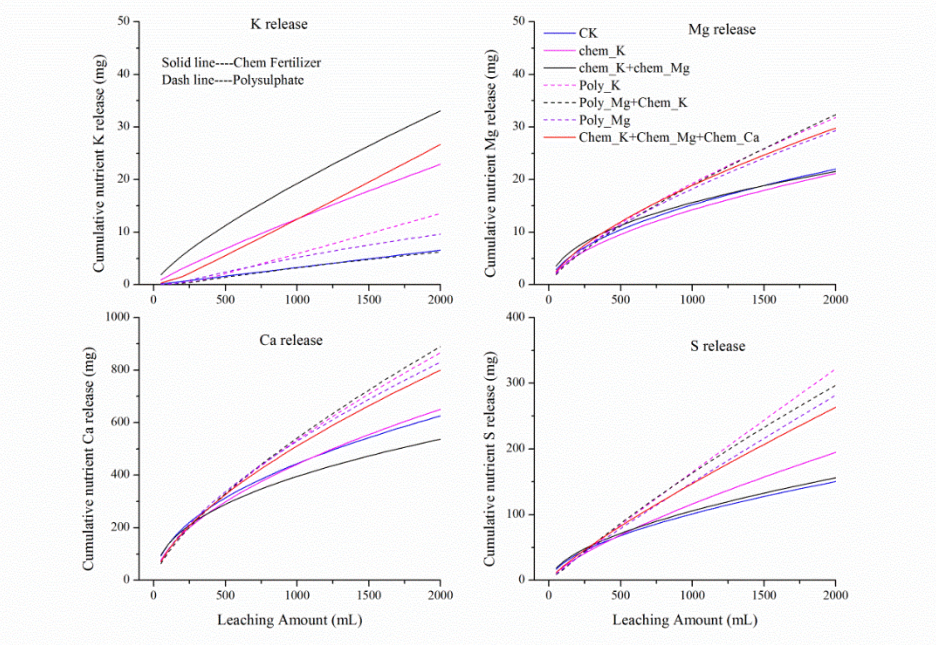

Figure 2 Dynamic of leaching of K, Mg, Ca and S

Element S was introduced by polyhalite fertilization and thus treatments with common chemical fertilizer showed less S collection both in the leachate of 2000 mL

and 5000 mL (Fig. 1 and 2).

2. Spring tea yield and quality

Compared with CK, K or Mg fertilization increased the young shoot yield by 3.8~45.2%. But significant yield increase by was only found in PolyK, while other treatments did not show any effect on young shoot yield compared with CK (Fig. 3).

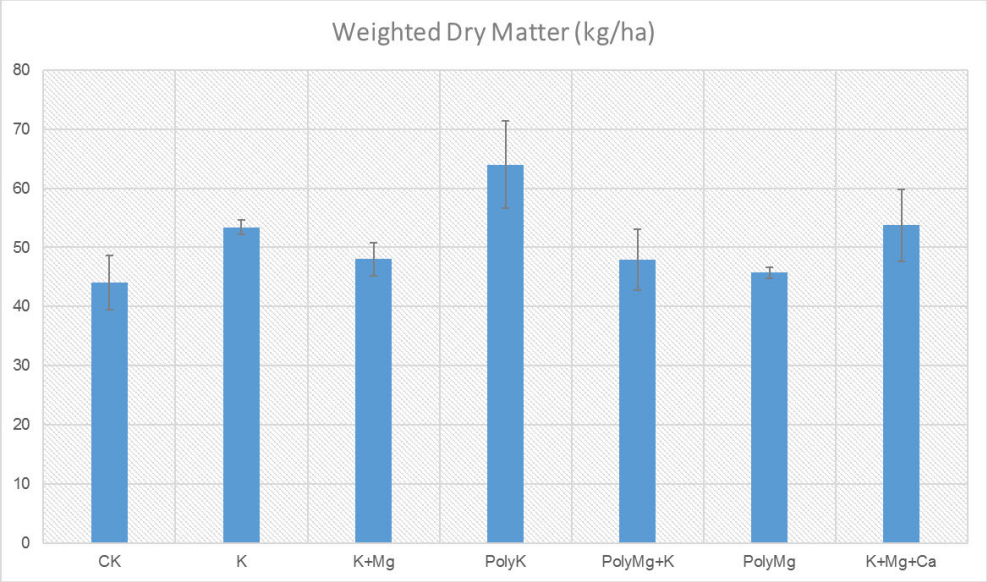

Fig. 3 Young shoot biomass harvested in spring

Tea quality in spring season is very important for price, especially for green tea. Compared with CK, addition of regular K and Mg improved the amino acid content by 4.5~14.5%, while 3 treatments with polyhalite addition increased the amino acid concentration by 21.9~26.18%. Single K and Mg application did not show any positive effect on polyphenols content, but polyhalite and Ca surplus also showed significantly higher polyphenols content, indicating the relationship between Ca and polyphenols accumulation. But for its high amino acid content, PloyK and PolyMg still showed the lowest PP:AA ration among 7 treatments, which indicating the high green tea quality for taste. However, due to the tea tree is a perennial woody crop, longer and extensive study is still required to test the effect of polyhalite in tea tree growth and quality components formation.

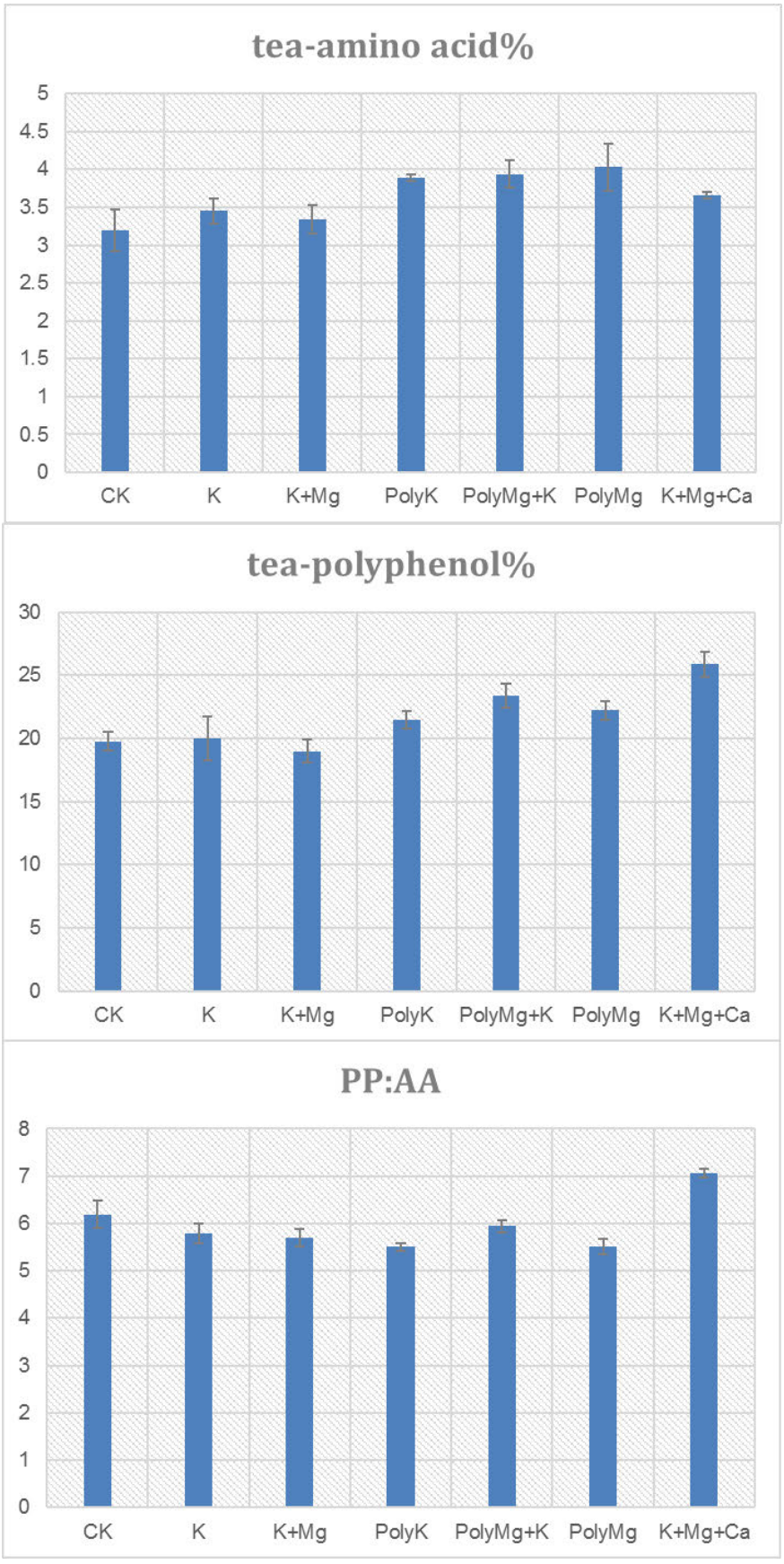

Fig. 4 Quality components in spring tea

3. Autumn tea quality

In autumn season, amino acid content is 50% lower than in spring season. Compared with regular K and Mg addition, polyhalite and compound showed highest amino acid content under N300. While under N500, polyhalite and compound did not show significant effect on amino acid content (Fig. 5).

Autumn season tea had higher polyphenols content than in spring tea. Both in N300 and N500, polyhalite showed low polyphenol content, thus caused lowest PP:AA ratio among 5 treatments. However, foliar application showed the lowest amino acid content and high PP:AA ratio.

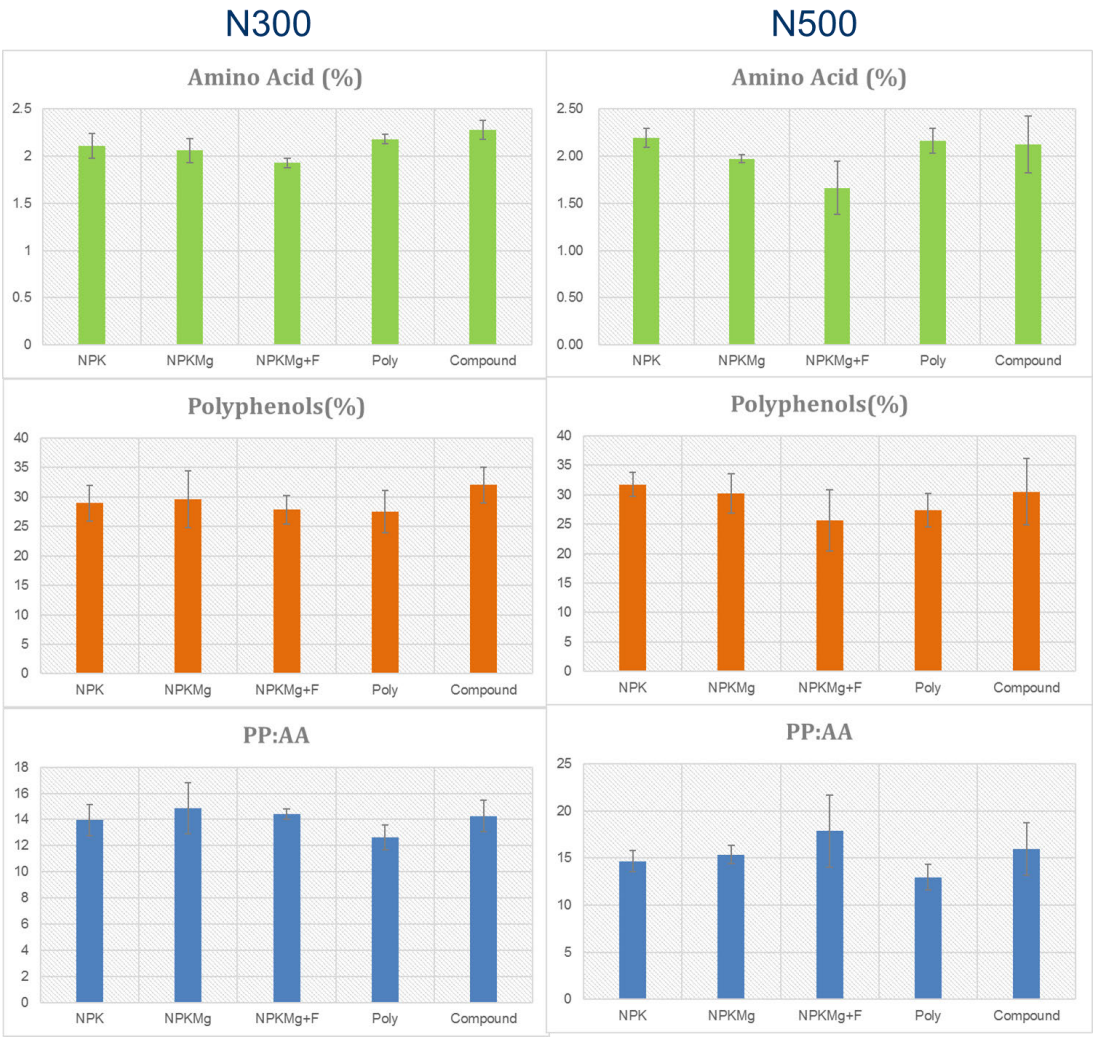

Fig. 5 Quality components in spring tea

Discussion

The less nutrient release rate in polyhalite may be due to its low solubility in liquid (Official document). This slow release effect could be beneficial for single application for K, Mg fertilizers in base fertilization and could long-term K and Mg supplying. The results that K and Mg mainly sustained in the top layer supported the expectation that polyhalite could reduce the nutrient leaching, and increase the soil K and Mg supplying capacity.

Addition of Ca is another worry about the application of polyhalite in tea gardens. In pot experiment, although PolyK treatment added the largest amount of Ca, but the yield was not significantly affected by polyhalite. Furthermore, Polyhalite addition showed the higher amino acid content, which is crucial for green tea quality. This effect could be due to the slow release of Ca, which does not excess the threshold. On the other hand, polyhalite and K+Mg+Ca showed higher polyphenols content, compared with K or K+Mg. It indicated that polyphenol accumulation may have relationship with Ca addition.

Although, it was reported that high soil exchangeable Ca content (>500 mg kg^{-1}) may harm the tea tree growth and quality. In field trial, different fertilizers did not show significant effect on amino acid and polyphenols content of autumn tea without the observation of adverse effect of Ca addition. It may also be due to the low application rate of polyhalite and low content of Ca and Mg in the studied soil. Nevertheless, the long-term effect of polyhalite application on tea plantation still requires more investigations.