Effects of Biogas Slurry Instead of Chemical Fertilizer on Soil Nutrients and Maize Growth

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Abstract: In order to explore the best ratio of chemical fertilizer and biogas slurry in the process of biogas slurry returning to the field, experiments were carried out with different fertilization methods such as different proportion of biogas slurry replacing chemical fertilizer and whether topdressing or not. When the proportion of biogas slurry instead of chemical fertilizer was 60% to 70%, the weight of per plant and leaf of maize reached the maximum value, which were 1064.37g and 959.13g, respectively. When the proportion of biogas slurry replacing chemical fertilizer were 60% to 70%, the content of available phosphorus was the highest. The content of soil total nitrogen, ammonium nitrogen and nitrate nitrogen was the highest when the proportion of biogas slurry replacing chemical fertilizer was 80%, and the content of soil alkali hydrolyzable nitrogen was the highest when the proportion of biogas slurry replacing chemical fertilizer was 70%. In terms of the yield of silage corn and the content of soil nutrients, and the effect is the best when the proportion of biogas slurry instead of chemical fertilizer was between 60% and 80%.

1 INTRODUCTION

Chinese government attaches great importance to the development of agricultural circular economy, recycling agricultural wastes, reducing the use of chemical fertilizers and protecting the environment, among which biogas project is the most typical example. Biogas slurry, as a by-product of rural biogas project, can provide fertilizer for crop growth, which is essential for the healthy and long-term development of rural areas. The comprehensive application of biogas slurry and chemical fertilizer provides higher grain yield and economic profitability (Ferdous 2020). As far as heavy metal pollution is concerned, it is safe and sustainable to apply appropriate amount of biogas slurry to farmland (Tang 2020). Excessive use of biogas slurry will adversely affect crops and increase the risk of environmental pollution (Chen 2017). Therefore, the purpose of this paper was to further determine the application amount of biogas slurry and the ratio of chemical fertilizer to biogas slurry in the process of biogas slurry returning.

2 MATERIALS AND METHODS

2.1 Experimental Materials

In this pot experiment, the soil is purple soil. Round flower pots with a diameter of 30 cm and a height of 25 cm were selected for the experiment, and each pot was filled with about 8.5 kg of air-dried soil, keeping the depth of the soil layer at 20 cm. Maize is a conventional variety. Biogas slurry was taken from Sichuan Xuebao Dairy Group Co Ltd. The nutrient content of the biogas slurry is 1.04 g kg-1 of nitrogen, 0.50 g kg-1 of phosphorus and 0.93 g kg-1 of potassium. Urea contained 46% nitrogen (N), potassium dihydrogen phosphate contained 24% phosphorus pentoxide (P_2O_5) and 27% potassium oxide (K_2O), and potassium chloride contained 62.7% potassium oxide (K_2O). The basic properties of soil samples in this test is presented in Table 1.

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2.2 Experimental Design

According to the determined nitrogen application rate, the biogas slurry and chemical fertilizer were divided into 6 groups according to different proportions. Each group was set with two different fertilization methods. The first was to use 60% nitrogen fertilizer as base fertilizer and 40% nitrogen fertilizer as topdressing. The second was to use 100% nitrogen fertilizer as base fertilizer and phosphorus and potassium fertilizer as base fertilizer at the same time. There were 12 treatments in total. The target yield of dry grain of silage maize is 7920 kg ha-1, and the total application amount of fertilizer is 203.55 kg ha^{-1} of nitrogen (N), 68.10 kg ha^{-1} of phosphorus pentoxide (P_2O_5) and 169.5 kg ha^{-1} of potassium oxide (K_2O). According to the fertilizer content and potting area of different chemical fertilizers, the amount of chemical fertilizer required for each pot is calculated. Specific fertilization amount in this test is presented in Table 2.

2.3 Determination Method

After 100 days of maize sowing, the physiological characters of plants and basic soil properties were measured. Plant physiological characters included: ground leaf weight, root weight, plant height, maximum stem circumference, number of leaves, maximum leaf length and maximum leaf width. The basic properties of soil included pH, moisture content, total nitrogen, total phosphorus, organic carbon, nitrate nitrogen, ammonium nitrogen, alkali hydrolyzable nitrogen and available phosphorus. pH was measured by potentiometric titration; Total nitrogen was determined by automatic nitrogen determinator; total P was determined by the sodium hydroxide (NaOH) extraction method (Wang 2014); Organic carbon was determined by potassium dichromate external heating method; Ammonia nitrogen was extracted with potassium chloride solution and determined by spectrophotometry; Available phosphorus was determined by Sodium hydrogen carbonate solution-Mo-Sb anti spectrophotometric method.

Table 1: Main nutrient content of potted soil.

Item	Total nitrogen ($g\ kg^{-1}$)	Total phosphorus ($g\ kg^{-1}$)	Alkali hydrolyzed nitrogen ($mg\ kg^{-1}$)	Available phosphorus ($mg\ kg^{-1}$)	Soil organic carbon ($g\ kg^{-1}$)
value	0.91	0.70	86.22	22.61	9.94

Table 2 Different experimental treatments of biogas slurry instead of chemical fertilizer

Proportion	Fertilization mode	Base fertilizer				Topdressing	
		Potassium dihydrogen phosphate(g)	Potassium chloride(g)	Urea (g)	Biogas slurry(mL)	Urea (g)	Biogas slurry (mL)
100%	SF	0.979	0.423	0.000	694.72	0.000	463.15
	SBN			0.000	1157.87	-	-
80%	SF	1.084	0.612	0.282	555.75	0.188	370.50
	SBN			0.470	926.25	-	-
70%	SF	1.137	0.707	0.423	486.28	0.282	324.19
	SBN			0.704	810.46	-	-
60%	SF	1.190	0.802	0.564	416.81	0.376	277.87
	SBN			0.939	694.68	-	-
40%	SF	1.295	0.991	0.845	277.87	0.564	185.25
	SBN			1.409	463.12	-	-
20%	SF	1.401	1.181	1.127	138.94	0.751	92.63
	SBN			1.879	231.56	-	-

Note: SF represents split fertilization; SBN represents single basal application.

3 RESULTS AND DISCUSSION

3.1 Effects of Different Proportions of Biogas Slurry and Chemical Fertilizer on Nutrients

In the staged fertilization method, with the increase of the proportion of biogas slurry replacing chemical fertilizer, the soil total phosphorus content first increased and then decreased, reaching the maximum when the proportion of biogas slurry replacing chemical fertilizer is 70%, while in the one-time fertilization method, the soil total phosphorus content is relatively high in the treatment of 20% and 80% of biogas slurry replacing chemical fertilizer (Fig. 1a), and there is no significant difference in other treatments. In both fertilization methods, the content of available phosphorus first increased and then decreased with the increase of the proportion of biogas slurry replacing chemical fertilizer. When the proportion of biogas slurry replacing chemical fertilizer was 60% and 70%, the content of rapidly available phosphorus was larger (Fig. 1b). Only when the proportion of biogas slurry insteaded of chemical fertilizer was 60% and 70%, the content of soil total phosphorus was higher by split fertilization than by one-time fertilization. The changes of soil available phosphorus and soil total phosphorus were the same, which indicated that under the proportion of 60% and 70% biogas slurry instead of chemical fertilizer, the content of soil total phosphorus and available phosphorus increased by split fertilization.

With the increase of the proportion of biogas slurry replacing chemical fertilizer, the contents of soil total nitrogen, alkali hydrolyzable nitrogen, ammonium nitrogen and nitrate nitrogen increased first and then decreased. The contents of soil total nitrogen, ammonium nitrogen and nitrate nitrogen were the highest when the proportion of biogas slurry replacing chemical fertilizer was 80%, while the contents of soil alkali hydrolyzable nitrogen were the highest when the proportion of biogas slurry replacing chemical fertilizer was 70% (Fig. 1c). The difference of soil total nitrogen under the two fertilization methods was not obvious (Fig. 1f). The alkali hydrolyzable nitrogen shows that the one-time fertilization method was greater than the split fertilization method. When the ratio of biogas slurry to chemical fertilizer was less than 70%, one-time fertilization was greater than split fertilization, while when the proportion of biogas slurry to chemical fertilizer is high (80% and 100%), one-time fertilization was less than split fertilization(Fig. 1e). The characteristics of soil nitrate nitrogen and soil ammonium nitrogen were opposite (Fig. 1d), indicating that in fertilization dominated by biogas slurry fertilizer, split fertilizationis conducive to the accumulation of soil ammonium nitrogen, while in the fertilization dominated by chemical fertilizer, split fertilization was conducive to the accumulation of nitrate nitrogen. Biogas slurry partially substituting chemical fertilizer could significantly improve soil fertility, including available nitrogen, phospho-rus, and potassium (Wang 2019). This is consistent with our research.

3.2 Effects of Different Proportions of Biogas Slurry and Chemical Fertilizer on Maize Growth

With the increase of the proportion of biogas slurry instead of chemical fertilizer, the weight of corn per plant and leaf weight first increased and then decreased under the two fertilization methods, both of which are larger in the proportion of biogas slurry instead of chemical fertilizer of 60% and 70% (Fig. 2a, b). When the ratio of biogas slurry to chemical fertilizer was not more than 70%, the weight of single plant and leaf of maize under one-time fertilization was greater than that under split fertilization. Under the treatment with higher ratio of biogas slurry to chemical fertilizer, the weight of single plant and leaf of Maize under split fertilization was greater than that under one-time fertilization. Under the condition of ensuring the same total amount of fertilization, when the proportion of biogas slurry application was relatively low, the effect of one-time fertilization was better than that of split fertilization. When the proportion of biogas slurry application increased to more than 80%, the effect of split fertilization was better than that of one-time fertilization. This is because biogas slurry belongs to liquid fertilizer, and most nutrients belong to water-soluble and available state. After one-time fertilization, nutrients may be lost with runoff; In addition, due to the large application amount of biogas slurry, one-time application may cause leakage, resulting in the loss of some biogas slurry nutrients. split fertilization can reduce the application amount of single biogas slurry.

When the proportion of biogas slurry instead of chemical fertilizer was 70%, the root weight of maize growed most vigorously (Fig. 2c). It can be clearly observed that the root fine whiskers increase.

At this time, the root weight of split fertilization treatment was 39.01% higher than that of one-time fertilization. The plant height of maize reaches the maximum when the proportion of biogas slurry replacing chemical fertilizer was 60% (Fig. 2d), and the maximum stem circumference and leaf number reached the maximum when the proportion of biogas slurry replacing chemical fertilizer was 70% (Fig. 2e, Fig. 2f). Under the best conditions, the effect of one-time fertilization was better than that of split fertilization. It can be found in combination with several physiological character indexes of maize, When the proportion of biogas slurry replacing chemical fertilizer was high, the effect of one-time fertilization is better than split fertilization. It is similar to that of Xu et al. (Xu 2021), which explains that biogas slurry partially replacing chemical fertilizer can improve the biological yield and feed quality of crops.

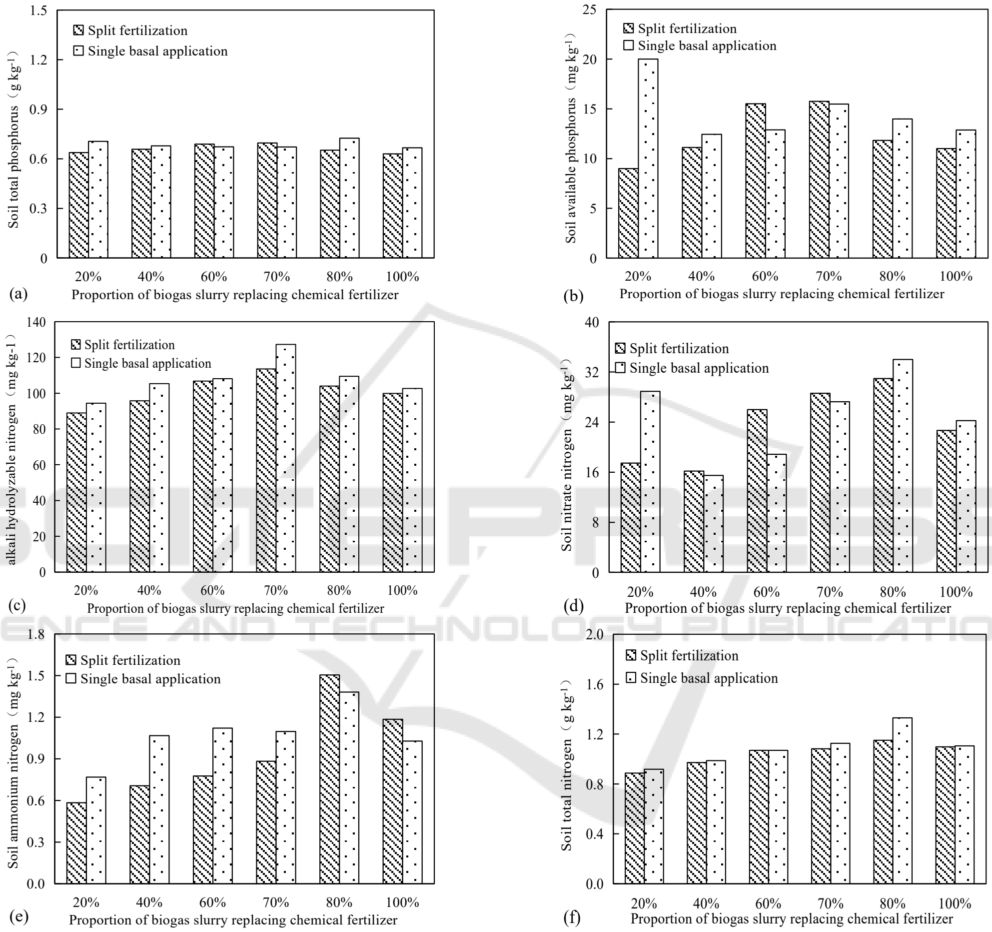
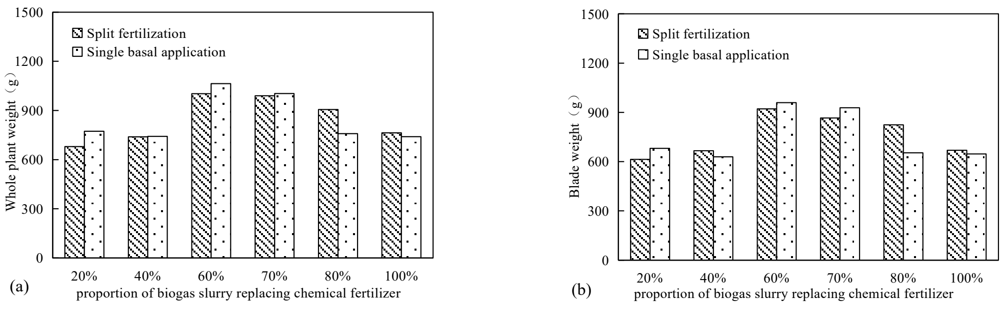


Figure 1.Effects of biogas slurry instead of chemical fertilizer on soil nutrients



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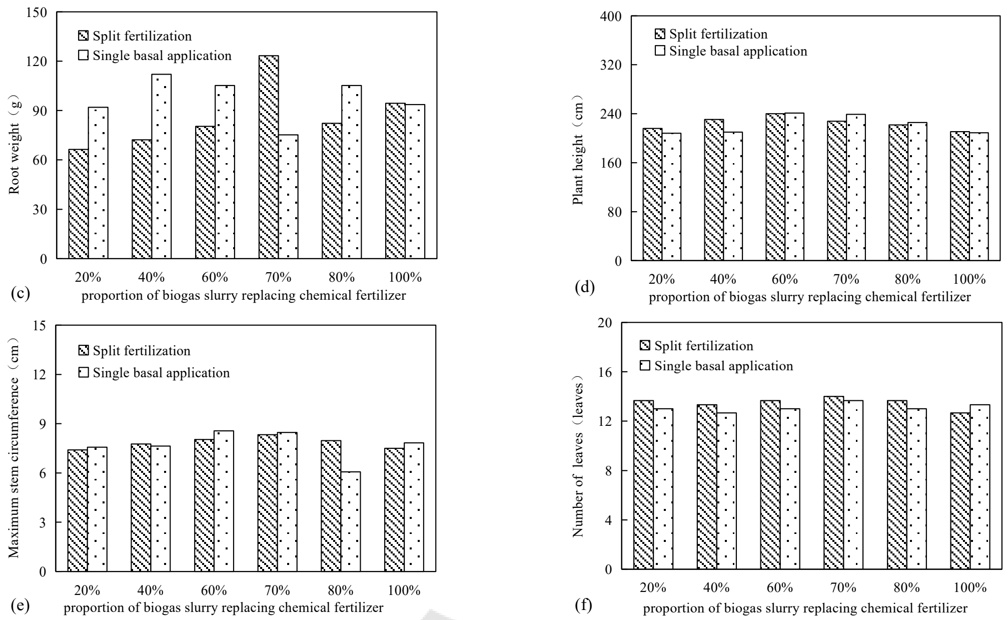

Figure 2: Effects of biogas slurry instead of chemical fertilizer on agronomic characters of maize.

4 CONCLUSION

The combined use of biogas slurry and chemical fertilizer can increase the utilization efficiency of nitrogen and phosphorus and increase the yield of silage corn. The maximum values of corn weight per plant and leaf weight were obtained in the range of 60% to 70% of biogas slurry instead of chemical fertilizer, and the maximum values were 1064.37 g and 959.13 g respectively. When the biogas slurry instead of chemical fertilizer was 60% and 70%, the silage corn yield of one-time fertilization was always greater than split fertilization. When the ratio of biogas slurry to chemical fertilizer is 80%, the maximum content of total phosphorus in soil can reach 725.31 mg kg^{-1}. When the ratio of biogas slurry to chemical fertilizer is 60% and 70%, the content of rapid available phosphorus is large, up to 15.76 mg kg^{-1};the content of soil total nitrogen, ammonium nitrogen and nitrate nitrogen was the highest when the proportion of biogas slurry replacing chemical fertilizer was 80%, while the content of soil alkali hydrolyzable nitrogen was the highest when the proportion of biogas slurry replacing chemical fertilizer was 70%, and the maximum values were 1.33 g kg^{-1}, 1.50 mg kg^{-1}, 33.99 mg kg^{-1} and 127.27 mg kg^{-1} , respectively. In terms of the yield of silage corn and the content of soil nutrients, and the effect is the best when the proportion of biogas slurry instead of chemical fertilizer was between 60% and 80%.

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