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REVIEW ON EFFECTS OF BIOGAS SLURRY APPLICATION ON CROP GROWTH

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Problem statement. Biogas slurry is a waste material of anaerobic fermentation that have been formed into the biogas stations using cows', pigs', horses', sheep's manure, chicken litter, sewage sludge plants residues [1; 2]. It is rich in organic matter, nitrogen and phosphorus and other nutrients. It is known that improper disposal will not only waste nutrient resources, but also bring pollution risks to the surrounding soil, surface water and groundwater [3; 4].

It was found that biogas slurry contains such important nutrients as NPK that are needed for crop growth. Also, slurry has such components as Fe, Mn, Zn, amino acids [3; 5–7], contain humic acid, gibberellin and other active substances that can improve plant growth [8–12]. Biogas slurry is a kind of organic fertilizer with complete nutrient content and fast or slow recovery [13–15]. Based on the concept of circular agriculture, converting biogas slurry into fertilizer can reduce or avoid the environmental risks caused by biogas slurry discharge. On the other hand, it can be utilized as resources to reduce the amount of chemical fertilizer applied in agricultural production and mitigate the harm caused by massive application of chemical fertilizer [16–19]. Thus, biogas slurry application improves the quality of agricultural products, yields of crops with significant economic and environmental benefits [20–22].

At present, biogas slurry is used as fertilizer in various food crops for example wheat [23; 24], rice [25–27], maize [28–32], vegetable: lettuce [33; 34], Chinese leek [35], Chinese cabbage [36; 37] and fruit – apple [38]. A very significant application effect was proofed, thus the position of biogas slurry in agriculture is becoming more and more important.

The purpose of this paper is a review about the effects of biogas slurry irrigation and biogas slurry spraying on photosynthesis, yield and quality of crops in the process of growth and development, in order to provide reference for the promotion and application of eco-agricultural cycle combining agriculture and animal husbandry.

Analysis of recent research and publications

1. Effects of biogas slurry application on photosynthetic characteristics of crops

Chlorophyll is the material basis of photosynthesis in higher plants [39], to a certain extent, chlorophyll content in leaves can reflect the photosynthetic capacity of plants [40–42], affecting crop yield [43]. As biogas slurry contains N, P, S, Mg and other major elements that constitute chlorophyll, protein and lamella film [44], application of biogas slurry can effectively improve chlorophyll content in leaves [45–47]. The enhancement of electron transport and stomatal opening is beneficial to the improvement of light energy capture, conversion efficiency and CO_2 fixation rate [48–50], thus improving the photosynthetic capacity of crop leaves [51; 52]. In particular, chlorophyll B is beneficial to absorb weak light, and its content affects the light capture ability of leaves [53]. Biogas slurry spraying increases the content of chlorophyll B, resulting in the increase of chlorophyll A + B content, thus facilitating the transmission and transformation of light energy [54; 55], plant adaptation to low light environment by improving the utilization efficiency of limited light resources in habitat [56; 57].

The study of Li Ran showed that the application of biogas slurry on bitter melon can improve photosynthetic indexes, reduce stomatal limit value, prolong the harvesting period and improve yield. The application effect is related to the concentration of biogas slurry [58]. Researcher's studies of wheat [51; 59], corn [60], tomato [21], cucumber [20] and apple [61]. Liu et al. [61] also showed that biogas slurry could significantly increase leaf nitrogen and chlorophyll content, and increase leaf photosynthetic rate (Pn), transpiration rate (Tr) and stomatal conductance Gs.

Leaf photosynthetic rate is affected by chlorophyll content and carboxylase activity. As is known, nitrogen is the main component of chlorophyll and carboxylase [62], so proper nitrogen supply can increase nitrogen and chlorophyll content of leaf [63] and prolong leaf function period [64]. Insufficient or excessive nitrogen supply can cause decreasing of chlorophyll content and inducing of leaf senescence [60; 65].

Biogas slurry nitrogen application alone reduced the photosynthetic performance of wheat plants and significantly reduced the yield. Therefore, base application of biogas slurry combined with topdressing of appropriate amount of urea had a positive effect on improving leaf photosynthetic performance and adjusting yield factors. The combined application ratio of biogas slurry with a small amount of base application (25%) and spring re-application of urea (75%) showed the best yield [66]. Study of Ren also showed that 60% biogas slurry +40% fertilizer treatment not only improved chlorophyll content and photosynthetic efficiency of leaves, but also provided sufficient photosynthetic products for the increase of plant height [65].

Photosynthesis is the core of dry matter production, and differences in photosynthetic capacity lead to the differences in dry matter accumulation and metabolism, which in turn affect crop growth and development and accumulation of economic yield [67; 68]. Moderate topdressing at different stages of wheat could increase net photosynthetic rate of leaves, delay the decline of net photosynthetic rate at late growth stage, and increase grain yield [69; 70], especially at booting stage and filling stage, when the contribution rate of photosynthesis of functional leaves to grains reached more than 80% [71]. Longshu No 5 Potato was sprayed with biogas slurry for three times during its growth stage and it had the highest photosynthetic rate, stomatal conductivity, intercellular CO_2 concentration and transpiration rate during starch accumulation stage, which was conducive to water and nutrient transport, organic matter synthesis and dry matter accumulation [72].

2. Effects of biogas slurry application on crop yield

Biogas slurry is rich in organic and inorganic nutrients such as nitrogen, phosphorus and potassium, amino acids, proteins, nucleic acids and sugars, which play a positive role in improving crop yield [73; 74]. The ultimate goal of agricultural production is getting high quality, high yield and low consumption [75], the yield is the most direct index to evaluate biogas slurry application. Therefore, researchers have carried out a large number of studies on the effect of biogas slurry application on crop yield [76; 77]. Biogas slurry is a high-quality liquid organic fertilizer. Although its nutrients are lower than those of chemical fertilizer, after anaerobic fermentation, nitrogen, phosphorus, potassium and other nutrients exist in an efficient state, which is easy for crops to absorb and more conducive to promoting crop growth [78]. Dong Jingjing et al. [79] applied biogas slurry instead of chemical fertilizer in rice field, which effectively promote tillering and increase yield. H.Y. Huang et al. [80] carried out isonitrogenous field experiments with different biogas slurry replacement ratio for two consecutive years, and the results showed that wheat yield was the highest under 50% biogas slurry replacement ratio, which increased by 7.8% compared with single fertilizer application. After the harvest of pepper using conventional inorganic fertilizer, applying certain concentration of biogas slurry can continue to harvest for 2 times. The longer harvest period means that more pepper can be harvested within a single planting cycle, thus achieving more economic benefits. The reason for the prolonged harvest period may be that the biogas slurry of livestock and poultry manure contains a large number of slow-release components such as organic matter and humic acid, which prolong the fertilizer efficiency and the harvest period [52], this is consistent with the results of pepper [81; 82], tomato [22] and peanut [83].

The application of biogas slurry significantly increased the physiological activity and growth of tomato plants, and increased the branch number, flower number of main stem and fruit weight of tomato. Compared with the control, the higher the application amount of biogas slurry is, the higher the tomato yield will be gotten [84; 85]. When the biogas slurry ratio reaches a certain value, it can meet the nutrient requirements of tomato, and increasing the biogas slurry ratio does not promote plant growth [15]. Different growth stages have different nutrient requirements. Application of 1:4 biogas slurry and water at flowering fruit setting period is beneficial to increase tomato plant height and stem diameter, it also can promote tomato plant growth [86]. Nutrient requirements are greater during the fruit expansion period than flowering fruit setting period [15].

Biogas slurry combined with chemical fertilizer can effectively improve the chemical properties of topsoil, improve crop stress resistance, promote crop growth and increase crop yield [87]. The study of Zhang [45] showed that cucumber yield increased by 13.60% – 44.86% compared with biogas slurry treatment and fertilizer treatment alone. Cui's study [88] showed that the ratio of 60% biogas slurry +40% fertilizers was the most suitable for the nutrient requirements of maize growth. With the increase ratio of biogas slurry, wheat yield showed a trend of first increase and then decrease, and the treatment with 50% biogas slurry was the most suitable [89], which was consistent with the research results of Li [90], with the increase of the proportion of biogas slurry, the nutrient growth of wheat is vigorous, Carbon nitrogen ratio imbalance and late ripening, grain weight and yield decrease [91], this result also has been found in other crops [92]. As nutrient types and contents of biogas slurry fermented with different seasons and raw materials are different, the optimal ratio and dosage of biogas slurry nitrogen should be determined comprehensively according to soil fertility, ecological conditions, production level, main target and variety type, and field management level [91]. Application of biogas slurry from livestock and poultry manure can not only increase crop yield, but also replace conventional inorganic fertilizer in the actual agricultural production process, so as to avoid the indiscriminate discharge of this precious agricultural resource and environmental pollution [52].

3. Effects of biogas slurry application on crop quality

Assimilates are the material basis of crop yield and quality. The factors promoting the production and accumulation of assimilates have obvious potential of increasing yield and improving quality [92]. Biogas slurry contains amino acids, humus, organic small molecules and bioactive substances needed for crop growth and development, which can better promote crop growth and nutrient absorption and play a key role in improving crop quality [92; 94]. Vitamin C, reducing sugar, amino acid and nitrate contents are important indicators of crop quality [22; 86].

The study of Tang [95] showed that biogas slurry application could significantly increase protein and minerals in rice. The study of Mao [96] showed that biogas slurry application had a great impact on VC content, nitrate nitrogen content and soluble sugar content of mustard. The study of Dong [97] showed that biogas slurry could significantly increase the contents of soluble solids, soluble sugar and VC in strawberry by mixing biogas slurry with fertilizer in different proportions. Application of biogas slurry could affect the quality of Cabbage, and the contents of total sugar, reducing sugar, free amino acid and vitamin

C increased, while the contents of nitrate decreased [98; 99], this may be due to amino acids and humic acids in biogas slurry can activate nitrate reductase in plants, thus reducing nitrate content in vegetables. Under the premise of applying the same total nutrients of N, P and K, the combined application of biogas slurry and chemical fertilizer could significantly promote the growth of tomato, significantly reduce the titratable acid content of tomato, and increase the vitamin C and soluble sugar content [100; 101], fruit quality was significantly improved [102]. The reasonable proportion of biogas slurry and chemical fertilizer not only guaranteed the demand of large nutrient elements for tomato growth, but also provides medium and trace elements and other active substances for quality improvement [65]. Zheng Jian's study also showed that different proportions of biogas slurry treatment at the flowering fruit setting period and the fruit expansion stage improved tomato quality [15].

Combined application of biogas slurry and chemical fertilizer can promote the increase of trace elements and improve grain quality of wheat plant [103]. Under the condition of constant nitrogen content, with the increase of biogas slurry nitrogen replacement ratio, grain protein content increased [93]. Multiple quality indexes such as dough and flour were improved [104].

Conclusions. As a high-quality organic fertilizer source, biogas slurry is rich in organic matter and various physiologically active substances of humus, which provides a reasonable C/N ratio for microbial growth and promotes microbial growth [105]. It has a good promotion effect on the improvement of photosynthetic characteristics, yield and quality during crop growth [106].

However, biogas slurry is not omnipotent, affected by the source of biogas slurry, crop types and soil types, the effect of biogas slurry application is also uneven. According to the material composition of biogas slurry and the fertilizer demand of crops, a certain amount of chemical fertilizer is added to biogas slurry, which has a good promotion effect on improving the effect of biogas slurry returning to the field and saves resources. It promotes multiple recycling of agricultural waste and has a good application prospect in high quality and efficient crops and clean agricultural production.

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Zhang Xihuan, Wu Dafu, Zakharchenko E.A. Review on effects of biogas slurry application on crop growth

Biogas slurry is a residual by-product of anaerobic fermentation using animal manure, sewage and various crop straws as raw materials, it contains nitrogen, phosphorus and potassium needed for crop growth, and is rich in trace elements such as iron, manganese and zinc as well as nutrients such as amino acids, which also contains humic acid, amino acid and gibberellin and other active substances that can stimulate and promote plant growth. Converting biogas slurry into fertilizer can reduce or avoid the environmental risks caused by biogas slurry discharge; on the other hand, it can be utilized as resources to reduce the amount of chemical fertilizer applied in agriculture and mitigate the harm caused by massive application of chemical fertilizer. Therefore, the application of biogas slurry plays a positive role in promoting the ecological cycle agricultural mode combining agriculture and animal husbandry. In this paper, the effects of biogas slurry application on photosynthesis, yield and quality of crops during their growth and development were reviewed. A large number of studies have shown that application of biogas slurry can satisfy of the nutrients needed for crop growth, enhance the photosynthetic capacity, increase production, improve the quality of agricultural products, has significant economic and environmental benefits. Affected by the source of biogas slurry, crop genotypes and soil types, the effect of biogas slurry application is also uneven. According to the material composition of biogas slurry and the fertilizer needs of crops, adding a certain amount of chemical fertilizer to biogas slurry can promote the effect of biogas slurry returning to the field and save resources. It promotes multiple recycling of agricultural waste and has a good application prospect in high quality and efficient crops and clean agricultural production.

Key words: biogas slurry, crop yield, photosynthesis, quality.

Чжан С., Ву Д., Захарченко Е.А. Вплив біогазової суспензії на ріст сільськогосподарських культур (оглядова стаття)

Біогазова суспензія є залишковим побічним продуктом анаеробного бродіння з використанням тваринного гною, стічних вод та різноманітної соломи сільськогосподарських культур як сировини, вона містить азот, фосфор і калій, необхідні для росту сільськогосподарських культур, і багата мікроелементами, такими як залізо, марганець і цинк, а також поживними речовинами, такими як амінокислоти, що також містять гумінову кислоту, амінокислоту та гіберелін та інші активні речовини, які можуть стимулювати та сприяти росту рослин. Перетворення суспензії біогазу в добрива може зменшити або допоможе уникнути екологічних ризиків, викликаних викидом біогазової суспензії; з іншого боку, його можна використовувати як ресурси для зменшення кількості хімічних добрив, що застосовуються у сільському господарстві, а також пом’якшення шкоди, заподіяної масовим застосуванням хімічних добрив. Тому застосування біогазової суспензії відіграє позитивну роль у розвитку екологічного циклу сільського господарства, що поєднує землеробство та тваринництво. **Метою цієї статті** є з'ясування впливу застосування біогазової суспензії на фотосинтез, урожайність та якість сільськогосподарських культур під час їх росту та розвитку на основі літературних даних. Велика кількість досліджень показала, що застосування біогазової суспензії може задовольнити поживні речовини, необхідні для росту сільськогосподарських культур, підвищити фотосинтетичну активність, збільшити врожайність, покращити якість сільськогосподарської продукції, і має значні економічні та екологічні переваги. Залежно від джерела біогазової суспензії, генотипів сільськогосподарських культур і типів ґрунту ефект від застосування біогазової суспензії буде різний. Знаючи склад біогазової суспензії та потреби культур у добривах, додавання певної кількості хімічних добрив до суспензії може сприяти ефекту повернення відходу на поле та заощадити ресурси. Він сприяє багаторазовій переробці сільськогосподарських залишків і має хороші перспективи застосування для сільськогосподарських культур.

Ключові слова: біогазова суспензія, урожай, фотосинтез, якість.