Perspective

‘White revolution’ to ‘white pollution’—agricultural plastic film mulch in China

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Abstract

Plastic film mulching has played an important role in Chinese agriculture due to its soil warming and moisture conservation effects. With the help of plastic film mulch technology, grain and cash crop yields have increased by 20–35% and 20–60%, respectively. The area of plastic film coverage in China reached approximately 20 million hectares, and the amount of plastic film used reached 1.25 million tons in 2011. While producing huge benefits, plastic film mulch technology has also brought on a series of pollution hazards. Large amounts of residual plastic film have detrimental effects on soil structure, water and nutrient transport and crop growth, thereby disrupting the agricultural environment and reducing crop production. To control pollution, the Chinese government urgently needs to elevate plastic film standards. Meanwhile, research and development of biodegradable mulch film and multi-functional mulch recovery machinery will help promote effective control and management of residual mulch pollution.

Keywords: agricultural plastic film, white pollution, control pollution

In the past 30 years, advancement in agricultural science and technology has caused great changes in agricultural production in China [1]. Plastic film mulching technology has remarkably improved grain crop yield and water use efficiency through conserving water, maintaining soil moisture, suppressing weeds, increasing temperature and improving cold tolerance. Nationwide, the technology has led to a 20–35% increase in grain crop yield and a 20–60% increase in cash crop yield. Maize, wheat, cotton and potato yields have increased by 33.7%, 33.2%, 26.1% and 36.7%, respectively, while their corresponding water use efficiency levels have increased by 38.9%, 30.2%, 30.2% and 37.8%, respectively [2]. At present, transformation of Chinese agriculture aims to establish an intensive, standardized, mechanized, industrialized and specialized modern agriculture system. In this regard, plastic film mulching technology plays a crucial role in enhancing regional agricultural production, ensuring food security and increasing income of farmers.

According to China Agricultural Statistical Yearbook [3], the volume of plastic film mulch used in China increased nearly four-fold from 319,000 tons to 1,245,000 tons from 1991 to 2011. Its annual growth rate is 7.1% and is expected to increase in the coming years. Accordingly, the total crop area covered with plastic film mulch similarly exhibited a sustained rate of growth, increasing from 117,000 hm² in 1982 to 4,909,000 hm² in 1991 to 19,791,000 hm² in 2011. Data from 1991, 2001 and 2011 were analyzed, and the distribution of plastic film mulch use intensity in China was calculated as follows: plastic film mulch use intensity = amount of plastic film mulch usage/regional arable land area. Over the past 20 years, all of the provinces and regions of China have shown increasing trends in plastic film mulch use.
intensity, with increase ranging from three- to ten-fold. The Northern regions exhibited greater growth, with higher absolute intensity. For example, the plastic film mulch use intensity in Xinjiang increased from 7.0 kg hm\(^{-2}\) in 1991 to 34.8 kg hm\(^{-2}\) in 2011 (1 kg plastic film can cover 150–250 m\(^{2}\) area). Over the next ten years, the cultivation area covered by plastic film mulch is expected to increase at a rate of 8–10%, with the covered crop area increasing from the current 20 million hm\(^{2}\) to above 30 million hm\(^{2}\) and plastic film mulch usage increasing from the current 1.2 million tons to above two million tons.

Despite benefits of plastic film mulch technology, however, its widespread use has generated large amounts of mulch residue. As a result, the application of plastic film mulch technology is evolving from ‘white revolution’ to ‘white pollution’ (figure 1). Since plastic film mulch is mainly composed of polyvinyl chloride, the residual mulch film does not readily degrade in soil. The problem is worsened by the low rate of plastic film mulch recovery due to mechanized cultivation and thin film (less than 0.008 mm). Investigation of the major plastic film mulch use areas in China indicated soil residual mulch levels of 50–260 kg hm\(^{-2}\) in arable lands with long-term plastic film mulch cover (over ten years) [2]. Large amounts of residual mulch film can lead to unsustainable farmland use and thereby affect the agricultural environment [2, 4]. The main considerations are as follows. (1) Effect on moisture and nutrient transport in soil. These changes primarily reflect the damage to the physical structure of soil by residual mulch, which blocks the infiltration of capillary water and natural water and affects the moisture absorption in soil. As a result, nutrient movement speed and moisture penetration are reduced. (2) Effect on crop emergence and root growth. Studies in Xinjiang showed that residual plastic film mulch levels of 200 kg hm\(^{-2}\) in the topsoil (0–20 cm) affected the emergence rate of cotton seeds and reduced cotton production by 15%. (3) Secondary salinization of soil. Studies showed that mulching for 5–20 consecutive years led to a 122–146% increase in the salt content of the topsoil. (4) Degradation of polyethylene residual mulch film is negligible with the possible formation of environmentally harmful chemical products such as phthalate esters [5], di-(2-ethylhexyl) phthalate, aldehydes and ketones.

Scientists in China have recognized the hazards from plastic film mulch pollution and taken measures to address the problem of residual plastic film mulch. However, due to technical and economic limitations, it remains difficult to apply these measures at a large-scale. Residual plastic film mulch pollution has become a serious issue and needs to be addressed from aspects of policy, regulation and technology in an all-round manner. (1) Improve mulch film standards and the relevant quality control mechanisms to increase mulch film recovery and enhance mulch film recycling [5]. The mulch film currently used in China is less than 0.008 mm thick; in contrast, the mulch film used in the US and European countries are generally 0.020 mm and in Japan 0.015 mm. In these countries, the better quality mulch film remains mostly intact after use, and nearly no residual plastic film mulch is left in farmland soil after mechanized recovery. (2) Accelerate development of biodegradable mulch film with reduced production cost to replace the mulch film most commonly used at

Figure 1. Plastic film mulching field in Tongchuang, Shaanxi and plastic mulch residue field in Shihezi, Xijiang, China.
present [6], which is primarily composed of polyvinyl chloride. (3) Accelerate research and development of lightweight, simple and multi-functional machinery for residual mulch film recovery. The key focus should be farm machinery and technical measures that can be used for both regular farming operations (such as plowing) and residual mulch film recovery. Thus, highly efficient mulch film recovery should be achieved without increasing operation cost and burden on farmers.

Plastic film mulching technology provides good water retention and warming effects. If residual mulch film pollution can be effectively controlled in China, the application of plastic film mulching technology in this country will provide a useful reference for improving crop yield and water use efficiency in other similar regions worldwide, particularly in regions with cold and arid climates.

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