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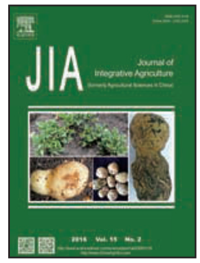

RESEARCH ARTICLE

Weed and insect control affected by mixing insecticides with glyphosate in cotton

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Abstract

Field studies were conducted in 2012 and 2013 to evaluate weed and insect control efficacy with glyphosate at 1 230 g ai (active ingredient) ha^{-1} and the insecticides acephate (728 g ai ha^{-1}), carbosulfan (135 g ai ha^{-1}), endosulfan (683 g ai ha^{-1}), imidacloprid (32 g ai ha^{-1}), or lambda-cyhalothrin (23 g ai ha^{-1}), as well as glyphosate tank-mixed with these insecticides. Four of the most common weeds in cotton, common purslane, false daisy, goosegrass, and lambsquarters, were manually sown in the cotton field and treated with glyphosate alone or in combination with insecticides. Glyphosate efficacy, based on visual estimates of control and weed fresh weight at 21 d after treatment (DAT), was unaffected by the addition of insecticides. Four weeds were controlled by 93–97% and 86–100% (visual rating) and reduced weed fresh biomass by 98–99% and 96–100% with glyphosate alone and its combination with insecticides, respectively. Addition of glyphosate to acephate improved cotton aphid control compared with acephate alone. However, addition of glyphosate to carbosulfan, endosulfan, imidacloprid, or lambda-cyhalothrin did not affect the aphid control when compared with the insecticide alone treatments. These results indicate that cotton producers could potentially integrate weed and insect management strategies by choosing suitable insecticide mixing partners with glyphosate, thereby reducing the application costs without sacrificing the efficacy of the glyphosate or the insecticides.

Keywords: aphid, control efficacy, glyphosate-resistant cotton, herbicide-insecticide combinations, weed

1. Introduction

China is one of the major cotton producers in the world with about 5 million ha in production averaged for over six decades (Mao 2013). However, the cotton growing area is increasingly under pressure due to higher production costs (10 200 CNY ha^{-1} in 2003 to 32 700 CNY ha^{-1} in 2013), especially the rapidly expanding labor costs (4 650 CNY ha^{-1} in 2003 to 20 400 CNY ha^{-1} in 2013; the Price Department of the National Development and Reform Commission of China 2014). Therefore, reducing production costs has become increasingly important to make cotton farming sustainable and viable. Transgenic *Bacillus thuringiensis* (Bt) cotton has been widely adopted in China since its initial commercial release in 1997 (Lu *et al.* 2010, 2012). In recent years, there has been an increasing trend of agricultural population migrating to the cities and the rural labor forces shifting to

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non-agricultural industries in China (summarized from the Statistical Bulletin of National Economic and Social Development, National Bureau of Statistics, China). Demand for glyphosate-resistant cotton is very strong in China. Up to now, there are some transgenic glyphosate-resistant cotton varieties now belonging to the cotton breeders in China (Wang *et al.* 2014; Zhang *et al.* 2014), which can lay the foundation for application to production in the near future. This technology is expected to alleviate the labor demand for manual weed control in cotton. Moreover, glyphosate-resistant cotton will provide growers the opportunity to use glyphosate in cotton (Edenfield *et al.* 2005; Main *et al.* 2007), potentially resulting in scenarios of the simultaneous glyphosate and insecticides applications through tank-mixture.

Cotton aphid (*Aphis gossypii* Glover) is the primary pest in cotton seedlings in the Yellow River cotton-producing area of China (Zhang 1992; Li *et al.* 2013). Aphids injure cotton seedlings by sucking the young leaves and stems, causing leaves to curl and reducing photosynthesis (Slosser *et al.* 2002). The widespread adoption of Bt cotton has reduced the use of broad-spectrum insecticides to control lepidopteran pests (Lu *et al.* 2010). Populations of sap-feeding pests, such as aphids, leafhoppers, spider mites, and mirid bugs, have increased due to fewer insecticide sprays in Bt cotton fields (Naranjo 2011; Hagenbucher *et al.* 2013; Ma *et al.* 2014). In addition, at the cotton seedling stage, most weed species are also at their early seedling stages and may be susceptible to glyphosate application. Consequently, optimum timing for insecticides and glyphosate application may coincide. A combination of a suitable insecticide with glyphosate may allow growers to control both weeds and insect pests with a single application in the glyphosate-resistant cotton field, thereby reducing fuel use, labor costs and equipment wear.

The compatibility of glyphosate-insecticide combinations on weed control has been previously evaluated in cotton. Scroggs *et al.* (2005) observed that insecticides acephate, acetamiprid, bifenthrin, cyfluthrin, cypermetherin, dicrotophos, dimethoate, emanectin benzoate, imidacloprid, indoxacarb, lambda-cyhalothrin, methoxy-fenozide, spinosad, thiamethoxam, and zeta-cypermethrin applied in mixture with glyphosate resulted in no reduction in visual weed control or biomass of barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), hemp sesbania (*Sesbania exaltata* (Raf.) Rydb.), johnsongrass (*Sorghum halepense* (L.) Per.), pitted morningglory (*Ipomoea lacunose* L.), and sicklepod (*Senna obtusifolia* (L.) Irwin and Barneby) compared with glyphosate alone. Similarly, Pankey *et al.* (2004) reported that acephate, dicrotophos, dimethoate, imidacloprid, lambda-cyhalothrin, oxamyl, and endosulfan did not affect the control efficacy of glyphosate on pitted morningglory, prickly sida (*Sida spinosa* L.), and redweed (*Melochia corchorifolia* L.); but applying lambda-cyhalothrin or fipronil with glyphosate reduced control of hemp sesbania by 19 and 9%, respectively, compared with glyphosate alone. Mascarenhas and Griffin (1997) also found that addition of imidacloprid to glyphosate reduced barnyardgrass control and that chlorpyrifos, fipronil, methamidophos, and imidacloprid mixed with glyphosate reduced pitted morningglory control compared to the glyphosate alone treatment.

The joint effects of glyphosate mixing with insecticides on insect control have also been investigated. Panky *et al.* (1999) reported that glyphosate tank mixtures with acephate, cyhalothrin, dimethoate, or imidacloprid did not antagonize thrips (*Frankliniella* spp.) control. Pankey *et al.* (2004) also reported that insect control was not reduced by glyphosate regardless of the insecticides, and mixture of glyphosate with dicrotophos and imidacloprid improved cotton aphid and thrips control respectively compared to insecticide alone. Sparks *et al.* (2003) also found that cotton bollworm (*Helicoverpa zea* Boddie (Lepidoptera: Noctuidae)) control was not reduced by the mixture of glyphosate and emamectin. However, Mascarenhas and Griffin (1997) found that the addition of glyphosate to oxydemeton-methyl reduced the aphid control in cotton.

With the intent of reducing inputs and costs in cotton, growers may find it beneficial to tank-mix glyphosate with insecticides to control both weeds and insects at the same time. However, many times pesticides work in an antagonistic manner when combined. The objective of this research was to determine if selected foliar-applied insecticides in mixture with glyphosate influence the control efficacy of glyphosate on weeds and conversely if glyphosate affects control efficacy of insecticides on aphid in cotton.

2. Results

2.1. Weed control with glyphosate and insecticide mixtures

Statistical analysis indicated that weed control was not influenced by the interaction of year and treatment. Glyphosate alone or in combination with insecticide provide similar control. Averaged across years, glyphosate alone controlled common purslane 93%, false daisy 97%, goosegrass 96%, and lambsquarters 95%, while glyphosate in combination with insecticides controlled these weed by 86 to 99%, 96 to 98%, 93 to 100%, and 92 to 97%, respectively (Table 1).

Glyphosate applied alone or with insecticides significantly reduced fresh weight of all weed species compared with the respective untreated controls 21 d after treatment (DAT). In addition, coapplication of insecticides with glyphosate did not antagonize control of weeds when compared with glyphosate applied alone. At 21 DAT glyphosate alone