INTRODUCTION

The cotton bollworm, *Helicoverpa armigera* (Lepidoptera: Noctuidae), is a polyphagous agricultural pest that widely distributed around the world (Tay et al., 2013). The characteristics of its aggressive nature, rapid reproduction and strong adaptability have brought huge economic losses to agriculture worldwide (Fitt, 1989; Mironidis et al., 2013; Wu & Guo, 2005). Although transgenic *Bacillus thuringiensis* (Bt) cotton has been introduced and played important roles in controlling *H. armigera* (Downes & Mahon, 2012; Huang et al., 2002; Wu et al., 2008), chemical pesticides, including pyrethroid and organophosphorus insecticides, are still widely used to control *H. armigera* and other insect pests in the fields (Martin et al., 2003; Patil et al., 2017; Wilson et al., 2018). However, a long-term and extensive...
application of insecticides has led to the resistance of *H. armigera* to many insecticides. For example, different field strains of *H. armigera* have developed high level resistance to pyrethroids (Bajya et al., 2011; Sene et al., 2020; Xu et al., 2016); *H. armigera* in Pakistan showed low to moderate level of resistance to indoxacarb, with resistance ratios ranging from 5.36- to 20.40-fold (Qayyum et al., 2015).  

Cytochrome P450s (P450s) is one of the major detoxification enzymes that can metabolize endogenous and exogenous compounds, including insecticides and other xenobiotics (Feyereisen, 2012; Scott, 2008). Inducibility is an important characteristic of P450s (Liu et al., 2015; Scott et al., 1996), which would help insects to better metabolize xenobiotics so that increase their adaptability to host plants and tolerance to insecticides (Mao et al., 2007; Tao et al., 2012). Previous studies have shown that insect cytochrome P450 genes can be induced by allelochemicals (Liu et al., 2006; Mao et al., 2007; Zhou et al., 2010) and some insecticides (Giraudo et al., 2015; Zhu et al., 2016). For example, quercetin induced the expression of CYP6B6 and CYP6B8 (Chen et al., 2018), and xanthotoxin induced that of CYP6AE19 and CYP6AE20 in *H. armigera* (Wang et al., 2018); fenvalerate induced the expression of CYP9A105 in Spodoptera exigua (Wang et al., 2018), DDT induced the expression of Cyp4p1 and Cyp4p2 in DDT resistant strain of Drosophila melanogaster (91-R) (Seong et al., 2019). The induction of P450s in response to phoxim and indoxacarb in Bombyx mori, Plutella xylostella and *S. exigua* has also been reported (Gao et al., 2018; Hu et al., 2019; Li et al., 2015; Wang et al., 2013). However, information on effects of insecticides on the expression of P450s in *H. armigera* is still limited.  

Cytochrome P450 CYP6B7 was first isolated and identified in pyrethroid-resistant *H. armigera* by Ranasinghe et al. (1998), Ranasinghe et al. (1999) in Australia, and it was later reported being overexpressed in a fenvalerate-selected resistant strain of *H. armigera* (Zhang et al., 2011); the sensitivity of *H. armigera* to fenvalerate increased after knockdown of CYP6B7 by RNA interference (Tang et al., 2012). These results indicated that CYP6B7 played a vital role in the resistance of *H. armigera* to pyrethroids. Ranasinghe and Hobbs (1999) reported that CYP6B7 in fat body culture of *H. armigera* (in vitro) could be induced by α-pinene, phenobarbital and some pyrethroids; Tao et al. (2012) suggested that gossypol and xanthotoxin significantly induced the expression of CYP6B7, and the gossypol-induced multiple P450s contributed to the tolerance of *H. armigera* to deltamethrin. The expression of CYP6B7 in *H. armigera* could also be significantly induced by other allelochemicals, including 2-tridecanone(Xu et al., 2018), flavone, coumarin, DIMBOA(2,4-Dihydroxy-7-methoxy-1,4-benzoxazin-3-one) and visnagin (Chen et al., 2019).  

Our preliminary study indicated that a BJ strain of *H. armigera*, which showed extremely high level of resistance to fenvalerate, had no cross-resistance to phoxim and indoxacarb. Although previous study has proved that fenvalerate could induce CYP6B7 in fat body culture of *H. armigera* in vitro, there was no report about the effects of fenvalerate on the expression of CYP6B7 in different tissues of *H. armigera* in vivo so far. Can fenvalerate induce the expression of CYP6B7 in a fenvalerate-resistant strain of *H. armigera*? What is the difference between the effect of fenvalerate and other insecticides that had no cross-resistance on the expression of CYP6B7? Is there difference between the induction of CYP6B7 in resistant and susceptible strains of *H. armigera*? Answers of these questions would help to understand the effects of insecticides with different resistance level on the expression of insect cytochrome P450 genes, and enrich the knowledge of P450s induction in insect pests. To figure out the answers, we focused on the effects of fenvalerate, phoxim and indoxacarb, to which the BJR strain of *H. armigera* showed different level of resistance, on the expression of CYP6B7 in *H. armigera* and compared the induction of CYP6B7 in response to the three insecticides between susceptible and resistant strains of *H. armigera* in the present study.

## MATERIALS AND METHODS

### Insects

The susceptible HDS strain of *H. armigera* was collected from field of Handan, Hebei Province, China, in 1988, and since then has been reared in the laboratory without exposure to insecticides. The resistant BJ strain, which showed 114.7-fold resistance to fenvalerate when it was first collected from field of Beijing in 2014 (Xu et al., 2016), was further selected by fenvalerate for more than 15 generations. The two strains of *H. armigera* were reared on artificial diets as described by Xu et al. (2016), with temperature of 27 ± 1°C, relative humidity of 70% ± 10% and light: dark photoperiod of 14:10 hr.

### Insecticides

The insecticides were used of technical grade: fenvalerate (93.4%) and deltamethrin (98%) were obtained from Jiangsu Changlong Chemical Co., Ltd, phoxim (90%), chlorpyrifos (95%) and methomyl (98%) were obtained from Beijing Huarong Biological Hormone Factory Co., Ltd, indoxacarb (96%) was obtained from Hubei Xianlong Chemical Co., Ltd, acetone was obtained from Sinopharm Chemical Reagent Co. Ltd.

### Determine resistance level of *H. armigera* to insecticides

Topical application method was used to determine the resistance levels of BJ strain of *H. armigera* to six commonly used insecticides via comparing with the susceptible HDS strain. Stock solution of six insecticides was prepared by acetone and diluted to 5–7 serial solutions of various concentration. One microlitre of test solution was applied on the thoracic dorsum of the third instar larvae (weight between 15 and 20 mg) of HDS and BJ strains by Hamilton syringe. Mortality was recorded at 48 hr after treatment with insecticide and acetone (as control). All treatments were conducted with at least 20 replicates for each treatment group with three replicates for each treatment.
three replicates, and twelve larvae for each replicate. The resistance ratios (RR) were calculated by dividing the LD\textsubscript{50} of the resistant BJR strain by the LD\textsubscript{50} of the susceptible HDS strain.

### 2.4 | Determine effects of insecticides on the expression level of CYP6B7 in *H. armigera*

#### 2.4.1 | Insecticides treatment

Based on the results of resistance determination, fenvalerate, phoxim and indoxacarb were used to investigate the effects of various insecticides on the expression of cytochrome P450 CYP6B7 in different tissues and different strains of *H. armigera*. The fifth instar larvae of HDS and BJR strains were selected and starved for 2 hr, then fed on artificial diets containing different concentration of insecticides for 72 hr, which was prepared by adding a certain amount of insecticide into 200 g unfrozen artificial diets and then mixing evenly. The concentrations of fenvalerate, phoxim, indoxacarb in artificial diets were 0.025 and 0.1 mg/g, 0.00625 and 0.025 mg/g, 0.00625 and 0.025 mg/g (W/W), respectively, which were set based on a preliminary study about the effects of insecticides on the body weight gain of treated larvae by about 30%-40% comparing to normal larvae (data not shown). The control diets were supplemented with acetone. Each treatment was replicated three times, with thirty larvae for each concentration.

#### 2.4.2 | RNA isolation and cDNA synthesis

After the fifth instar larvae were treated by fenvalerate, phoxim and indoxacarb for 24, 48 and 72 hr, respectively, total RNA was extracted from the midgut, fat body and cuticle of larvae using TaKaRa MiniBEST Universal RNA Extraction Kit (TaKaRa) according to the manufacturer's recommendations. The quality and integrity of RNA were measured using 1% gel electrophoresis and a Nanodrop spectrophotometer (Denovix company). One microgram total RNA was reverse-transcribed into cDNA using FastQuant RT Kit (With gDNase) (TIANGEN) according to the manufacturer’s protocol. The quality and quantity of cDNA were checked using a Nanodrop microspectrophotometer before quantitative real-time PCR.

#### 2.4.3 | Quantitative real-time PCR

Quantitative RT-PCR was performed on an ABI Prism7500 Real-Time PCR System (Applied Biosystems by Life Technologies) with SuperReal PreMix Plus (SYBR Green, TIANGEN), following a two-step protocol: 95°C for 15 min, 40 cycles of denaturing at 95°C for 10 s, annealing at 60°C for 20 s and extension at 72°C for 32 s. A melting curve was added as a final step to make sure the PCR product was unique and specific. PCR primers were designed using the Primer Premier 6.0 software based on the sequences published in NCBI for CYP6B7 (Accession No: DQ497428.2, CYP6B7-F: AAAGGCCACACCCCTTGCTAC, CYP6B7-R: GTCAAGGAACGCTTTCAAAAGT). A housekeeping gene, RPS15 (Accession No: AY818611.1, RPS15-F: AGAGAGATGATCGGCCACTAC, RPS15-R: TGTTGTCAGGCCACCACTT), was used to normalize the gene expression level (Shakeel et al., 2015). At least three sample repetitions and three technical repetitions were required for each test.

### 2.5 | Statistical analysis

The insecticide LD\textsubscript{50} values to *H. armigera* and the differences between control and treatment were analysed with SPSS (version 16.0). The gene expression level was calculated according to the $2^{-\Delta\Delta Ct}$ method (Livak & Schmittgen, 2001). The values were shown as means ± standard deviation derived from three biological repeats. A p-value <.05 indicates statistically significant differences according to Duncan test.

### 3 | RESULTS

#### 3.1 | Resistance level of *H. armigera* to six insecticides

The toxicity of six commonly used insecticides to *H. armigera* was determined by topical application method. When compared with the susceptible HDS strain, BJR strain showed extremely high level of resistance to fenvalerate, with LD\textsubscript{50} and resistance ratio (RR) values of 242.85 μg/larva and 1990.57-fold, respectively; and it showed middle level of resistance to deltamethrin, with LD\textsubscript{50} and RR values of 2.607 μg/larva and 5.48-fold, respectively; meanwhile, BJR strain was susceptible to the other four insecticides, including phoxim, chlorpyrifos, methomyl and indoxacarb, with LD\textsubscript{50} values ranging from 0.010 to 1.569 μg/larva, and RR values ranging from 1.48- to 2.44-fold (Table 1). These results indicated that there was cross-resistance between pyrethroid insecticides fenvalerate and deltamethrin, but no cross-resistance between pyrethroids and other insecticides tested.

#### 3.2 | Effects of insecticides on the expression level of P450 CYP6B7 in *H. armigera*

To analyse the effects of fenvalerate on the expression of CYP6B7 in different tissues of *H. armigera*, the fifth instar larvae of HDS and BJR strains were fed on diets containing 0.025 and 0.1 mg/g (W/W)
fenvalerate for 24, 48 and 72 hr, respectively, and the relative transcript levels of \( \text{CYP6B7} \) in midgut, fat body and cuticle of HDS and BJR strains were determined. The results were as following:

In HDS strain, the expression level of \( \text{CYP6B7} \) in midgut was increased by 4.6- and 13.7-fold, respectively, while that in fat body and cuticle was not changed significantly, after exposure to 0.025 and 0.1 mg/g fenvalerate for 24 hr when compared with that of the control (Figure 1a); the expression level of \( \text{CYP6B7} \) in midgut and fat body was induced by 1.8- and 3.2-fold, respectively, after exposure to 0.1 mg/g fenvalerate for 48 hr; but no significant induction was observed after exposure to 0.025 mg/g fenvalerate, as well as in cuticle after exposure to 0.025 and 0.1 mg/g fenvalerate (Figure 1b); the expression level in fat body was increased by 14.4- and 27.9-fold after exposure to 0.025 and 0.1 mg/g fenvalerate for 72 hr, respectively, while that in midgut and cuticle were not induced (Figure 1c).

In BJR strain, the expression level of \( \text{CYP6B7} \) in midgut was significantly induced by 86.6-fold after 24 hr exposure to 0.025 mg/g fenvalerate; meanwhile that in fat body and cuticle was induced by 14.4- and 27.9-fold, respectively, after exposure to 0.025 mg/g fenvalerate in diets when compared with that of the control (Figure 1d). The expression level was induced by 15.6- and 4.6-fold in midgut and fat body, respectively, after 48 hr of 0.025 mg/g fenvalerate exposure; meanwhile the expression was significantly inhibited at 72 hr after 0.00625 and 0.025 mg/g fenvalerate exposure when compared with that of the control (Figure 2a).

The expression level of \( \text{CYP6B7} \) in midgut of BJR strain of \( H. \text{armigera} \) was induced by 183.4- , 2.2- and 1.6-fold at 24, 48 and 72 hr, respectively, after exposure to 0.00625 mg/g phoxim and was induced by 316.8- , 10.3- and 1.6-fold at 24, 48 and 72 hr, respectively, after exposure to 0.025 mg/g phoxim when compared with that of the control (Figure 2b).

The results demonstrated that the expression level of \( \text{CYP6B7} \) in midgut of HDS strain of \( H. \text{armigera} \) was induced by 4.4-fold at 24 hr after 0.00625 mg/g indoxacarb exposure and was induced by 1.3-fold at 48 hr after 0.00625 mg/g indoxacarb exposure; but no significant induction was observed at 48 hr after 0.00625 mg/g indoxacarb exposure; moreover, the expression was significantly inhibited at 72 hr after 0.00625 and 0.025 mg/g indoxacarb exposure when compared with that of the control (Figure 3a).

The expression level of \( \text{CYP6B7} \) in midgut of BJR strain of \( H. \text{armigera} \) was induced by 1.6- and 1.3-fold, respectively, at 72 hr after exposure to 0.00625 and 0.025 mg/g indoxacarb, but no induction was observed at 24 and 48 hr (Figure 3b).

| Insecticides | Strain | \( \text{LD}_{50} \) (\( \mu \text{g/larva} \)) | 95% confident interval (\( \mu \text{g/larva} \)) | RR |
|--------------|--------|-----------------------------|---------------------------------|-----|
| Fenvalerate  | HDS    | 0.122                       | 0.094–0.153                      | 1   |
|              | BJR    | 242.850                     | 133.691–455.674                  | 1990.57 |
| Deltamethrin | HDS    | 0.476                       | 0.340–0.615                      | 1   |
|              | BJR    | 2.607                       | 1.591–1.7.203                    | 5.48 |
| Phoxim       | HDS    | 0.370                       | 0.252–0.511                      | 1   |
|              | BJR    | 0.606                       | 0.435–0.877                      | 1.64 |
| Chlorpyrifos | HDS    | 1.061                       | 0.812–1.374                      | 1   |
|              | BJR    | 1.569                       | 1.220–2.076                      | 1.48 |
| Methomyl     | HDS    | 0.283                       | 0.159–0.418                      | 1   |
|              | BJR    | 0.690                       | 0.480–1.088                      | 2.44 |
| Indoxacarb   | HDS    | 0.006                       | 0.003–0.008                      | 1   |
|              | BJR    | 0.010                       | 0.006–0.014                      | 1.67 |

Note: RR, \( \text{LD}_{50} \) of BJR strain/\( \text{LD}_{50} \) of HDS strain.

**TABLE 1** Resistance level of \( H. \text{armigera} \) to six commonly used insecticides.
Previous study indicated that the expression of detoxification-related genes in different tissues was related to their biological and physiological roles (Chen et al., 2019; Chung et al., 2009; Wang et al., 2018). Since most toxic substances enter insects by way of food intake, midgut as the primary detoxification organ usually contains many P450 enzymes to metabolize the xenobiotics (Wang et al., 2015; Zhang et al., 2016). Similarly, the insect fat body is also important tissue involved in xenobiotic metabolism (Snyder et al., 1995; Yang et al., 2007, 2014). Insect P450s associated with detoxification are usually highly expressed in these tissues. For example, CYP4M14, CYP6B50, CYP18B1, CYP301A1, CYP9A11 and CYP6AE70 were expressed the highest in midgut of S. exigua (Hu et al., 2019), and CYP6FV12 was expressed the highest in midgut of Bradysia odoriphaga, followed by fat body (Chen et al., 2019). Similar results were obtained in the present study, which revealed that the expression of CYP6B7 in midgut was significantly higher than that in fat body and cuticle in both HDS and BJR strains. 

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Cytochrome P450s can be induced by endogenous and exogenous compounds, suggesting they are involved in the adaptability of
insects to the environment, as well as the development of insecticide resistance (Clements et al., 2017; Mao et al., 2007; Tao et al., 2012). Previous study has proved that CYP6B7 could be induced by fenvalerate in fat body culture of H. armigera (in vitro) (Ranasinghe et al., 1999), in addition, six P450 genes (CYP6AE14, CYP6B2, CYP6B6, CYP6B7, CYP9A12, and CYP9A17) and four P450 genes (CYP6AE14, CYP6B2, CYP6B6, CYP9A14) were significantly induced by deltamethrin in the midgut and fat body of H. armigera, respectively (Zhou et al., 2010). In the present study, the expression of CYP6B7 could be induced in three major tissues (midgut, fat body and cuticle) of H. armigera after exposure to fenvalerate in diets; however, the induction level varied in different tissues; the maximum induction of CYP6B7 was observed in midgut of both susceptible and resistant strains, followed by fat body and cuticle. These results suggested that the induction of P450s is tissue-dependent, and P450s in midguts is more easily responded to xenobiotics when they enter the insect by feeding, which may make it easier for the insects adapt to the environment.

The induction of P450s might be dependent on the exposure methods, inducers, exposure dose and time (Baek et al., 2010; Jin et al., 2017; Zhang et al., 2016; Zhou et al., 2010). Beak et al. (2010) reported that the induction of P450s in response to cypermethrin was more significant by leaf dip method than by topical application in Plutella xylostella, and Zhang et al. (2016) suggested that the induction of P450 genes was related to the exposure dose and time of fipronil in Solenopsis invicta. In the present study, we investigated and compared the inducing effect of CYP6B7 in response to three insecticides (fenvalerate, phoxim and indoxacarb) in HDS and BJR strains of H. armigera. The induction of CYP6B7 in midgut enhanced with the increase of fenvalerate concentration at 48 hr in both HDS and BJR strains; simultaneously, the expression level of CYP6B7 was increased with the extension of exposure time; after exposure to 0.1 mg/g fenvalerate, the expression was not changed significantly at 24 hr, but induced by 127.9-fold at 48 hr in BJR strain. In addition, the expression of CYP6B7 was induced the most strongly by fenvalerate, followed by phoxim and indoxacarb. Taken together, our results suggested that the inducibility of CYP6B7 in H. armigera was affected by the exposure dose, time and type of insecticide, which further confirmed the results of previous studies mentioned above.

When compared the effect of three insecticides on the expression of CYP6B7 between the susceptible HDS and resistant BJR strains of H. armigera, we found that the induction of CYP6B7

![Figure 2](image1.png)  
**Figure 2** Relative expression level of CYP6B7 in midgut of HDS (a) and BJR strains (b) of H. armigera after exposure to phoxim in diets for different time period. Data shown are means ± SD of three biological repeats (n = 3). Different letters above bars indicate significant differences (p < .05) according to Duncan test. [Colour figure can be viewed at wileyonlinelibrary.com]

![Figure 3](image2.png)  
**Figure 3** Relative expression level of CYP6B7 in midgut of HDS (a) and BJR strains (b) of H. armigera after exposure to indoxacarb in diets for different time period. Data shown are means ± SD of three biological repeats (n = 3). Different letters above bars indicate significant differences (p < .05) according to Duncan test. [Colour figure can be viewed at wileyonlinelibrary.com]
in midgut of BJR strain was significantly higher than that of HDS strain after exposure to fenvalerate for 24 and 48 hr, and the induction of CYP6B7 in fat body and cuticle of BJR strain was significantly higher than that of HDS strain after exposure to fenvalerate for 72 hr. The induction of CYP6B7 in BJR strain was also stronger than that in the HDS strain after exposure to phoxim for different time points, but similar results were observed only after 72 hr of exposure to indoxacarb. These results suggested that the responses of CYP6B7 to insecticides between susceptible and resistant strains of *H. armigera* were different. Such difference has also been reported in other insects. In *D. melanogaster*, CYP6A2 was over-transcribed in a resistant strain, but not significantly changed in a susceptible strain after DDT treatment (Sun et al., 2011); in *Culex quinquefasciatus*, CYP6AA7, CYP9J34 and CYP9M10 were induced by permethrin in a resistant strain; however, no significant induction was observed in a susceptible strain (Liu et al., 2011); in *P. xylostella*, the induction of Cyp4M19, Cyp4M21, Cyp4M22, Cyp4M23, Cyp6CN1, Cyp6BF1, Cyp6BG1 and Cyp9G4 were more obvious in a resistant strain than that in a susceptible strain after exposure to 1 ppm cypermethrin (Baek et al., 2010); in *Chilo suppressalis*, the induction of CYP6CV5, CYP9A68, CYP321F3 and CYP324A12 was stronger in a chlorantraniliprole resistant strain than that in a susceptible strain (Xu et al., 2019).

Many previous studies suggested that the induction of insects P450s by xenobiotics was complicated (Stevens et al., 2000; Tian et al., 2019; Zhou et al., 2010), this was further confirmed in our study. In addition to the results mentioned above, the response of CYP6B7 to the treatment of low and high concentration of insecticide would be different even in the same tissue of *H. armigera*. E.g., the expression level of CYP6B7 in midgut of BJR strain was significantly induced by 86.6-fold after 24 hr exposure to 0.025 mg/g fenvalerate, but no induction was observed after exposure to 0.1 mg/g fenvalerate when compared with the control; moreover, the three insecticides at different concentration showed different effects (induction or suppression) on the transcript of CYP6B7 in some tissues of BJR and HDS strains (Figure 1, Figure 2, Figure 3). Similar results were reported by Zhou et al. (2010), the expression of CYP6B2, CYP6B7 and CYP9A17 in midgut of *H. armigera* were induced by 0.005 mg/g deltamethrin, whereas that was not induced by 0.5 mg/g deltamethrin; moreover, the expression of CYP6B7 in fat body was significantly suppressed by 0.5 mg/g deltamethrin. Since insecticides are toxic to insects, we speculate that suppression of CYP6B7 would occur when the concentration of toxic substances was high to an extent. Meanwhile, the induction of CYP6B7 by fenvalerate, phoxim and indoxacarb in *H. armigera*, to which the insect showed different level of resistance, were also different. This result is consistent with that of some previous studies. In *Diaphorina citri*, eight insecticides (chlorpyriphos, bifenthrin, lambda-cyhalothrin, thiamethoxam, clothianidin, dinotefuran, acetamiprid and chlorfenapyr) with varying resistance levels showed different induction level of CYP4g15, CYP303A1, CYP4C62, CYP6D5 (Tian et al., 2019); in *Aedes aegypti*, the induction of eleven P450s were different after exposure to permethrin and temephos, to which the resistance levels of *A. aegypti* was different (Poupardin et al., 2008).

Many studies have shown that cytochrome P450s were involved in the metabolism and detoxification of insecticides (Wang et al., 2018; War et al., 2011). In *H. armigera*, CYP6B6 was significantly induced by pyrethroid insecticides and involved in the detoxification of esfenvalerate (Feyereisen, 2006; Tian et al., 2017; Zhou et al., 2010); in *Spodoptera litura*, CYP9A40 was induced significantly by deltamethrin and methoxyfenozide and participated in the detoxification of the two insecticides (Wang et al., 2015). In our study, the expression of CYP6B7 was significantly induced by fenvalerate, phoxim and indoxacarb, since previous studies have confirmed that CYP6B7 was involved in fenvalerate detoxification in *H. armigera* (Tang et al., 2012; Zhao et al., 2017), herein, we speculated that CYP6B7 may also be involved in the metabolism of phoxim and indoxacarb in *H. armigera*. However, further study is needed for this conclusion.

In summary, the results of the present study indicated that CYP6B7 could be induced by fenvalerate, phoxim and indoxacarb in both resistant and susceptible strains of *H. armigera*, but the induction levels were different among the three insecticides; The induction of CYP6B7 is tissue-dependent, with the highest induction level observed in midguts; Moreover, the induction of CYP6B7 in the resistant BJr strain was more significant than that in the susceptible HDS strain after exposure to fenvalerate and phoxim, while that was opposite after indoxacarb treatment. Taken together, our results suggested the induction of CYP6B7 in *H. armigera* varied with the types of insecticides, exposure dose and time, insect tissues and strains.

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CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

AUTHORS’ CONTRIBUTIONS
YH, YyL and LhQ conceived and designed the experiments. YH and YyL performed the experiments. YH analysed the data. YyL, YhL and LhQ contributed reagents and materials. YH and LhQ drafted and revised the manuscript. All authors approved the final version of the article, including the authorship list.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are publicly available at http://doi.org/10.5281/zenodo.4087760.

ORCID
Yun Huang https://orcid.org/0000-0001-8735-1089
Yuanyuan Luo https://orcid.org/0000-0003-3714-4924
Peizhuo Wu https://orcid.org/0000-0003-2263-2140
Junyue Zheng https://orcid.org/0000-0002-8522-9474
Lihong Qiu https://orcid.org/0000-0002-4635-7641
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