王熠,张利军,陆俊姣,等.中药白头翁提取物对粘虫和小菜蛾的杀虫活性[J].山西农业大学学报(自然科学版),2025,45(6):117-125.
Wang Y, Zhang L J, Lu J J, et al. Insecticidal activity of the traditional chinese medicine *Pulsatilla chinensis* (Bge.) Regel *against Mythimna separata* (Walker) and *Plutella xylostella* (Linnaeus)[J]. Journal of Shanxi Agricultural University(Natural Science Edition), 2025,45(6):117-125.
doi: 10.13842/j.cnki.issn1671-8151.202503046

中药白头翁提取物对粘虫和小菜蛾的杀虫活性

王熠,张利军,陆俊姣,闫喜中

(山西农业大学 植物保护学院,山西 晋中 030801)

摘　要:[目的]评估中药白头翁在杀虫方面的应用价值。[方法]本试验以粘虫和小菜蛾作为供试害虫,采用浸渍法、小叶碟添加法以及微量点滴法,测定白头翁乙醇提取物对这2种害虫的杀卵、拒食、胃毒以及触杀活性。[结果]杀卵作用方面,白头翁对粘虫卵的LC_{50}值为57.72 mg/mL,对小菜蛾卵的LC_{50}值为2.22 mg/mL。拒食作用方面,24和48 h时白头翁对3龄粘虫幼虫的AFC_{50}值分别为78.70和63.39 mg/mL,对3龄小菜蛾幼虫的AFC_{50}值分别为32.79和11.16 mg/mL。胃毒作用方面,72、96和120 h时白头翁对3龄粘虫幼虫LC_{50}值分别为122.28、89.33、63.47 mg/mL,对3龄小菜蛾幼虫的LC_{50}值分别为1 235.66、619.16、178.85 μg/mL。触杀作用方面,白头翁对3龄粘虫幼虫没有触杀活性,24、48和72 h时白头翁对3龄小菜蛾幼虫的LC_{50}值分别为51.48、20.52、2.06 mg/mL。[结论]中药白头翁对小菜蛾的杀虫活性要好于对粘虫的,可作为防治小菜蛾的植物源杀虫剂进行进一步的研究开发。

关键词:中药白头翁;粘虫;小菜蛾;杀虫活性
中图分类号:S433.4　　**文献标识码**:A　　**文章编号**:1671-8151(2025)06-0117-09

Insecticidal activity of the traditional Chinese medicine *Pulsatilla chinensis* (Bge.) Regel *against Mythimna separata* (Walker) and *Plutella xylostella* (Linnaeus)

Wang Yi, Zhang Lijun, Lu Junjiao, Yan Xizhong

(*College Plant Protect, Shanxi Agriculture University, Jinzhong 030801, China*)

Abstract: [Objective] The purpose of this study was to assess the potential application value of traditional Chinese medicine *Pulsatilla chinensis* in insect control. [Methods] In this experiment, *M. separate* and *P. xylostella* were used as test insects. The ovicidal, antifeedant, stomach toxicity, and contact activities of the ethanol extract of *P. chinensis* against these two pests were determined using the dipping method, leaf-disc addition method, and micro-topical application method. [Results] In terms of ovicidal activity, the LC_{50} values of *P. chinensis* against *M. separate* eggs and *P. xylostella* eggs were 57.72 mg/mL and 2.22 mg/mL, respectively. For antifeedant activity, the AFC_{50} values against 3rd instar *M. separate* larvae at 24 h and 48 h were 78.70 and 63.39 mg/mL, respectively, while, the values against 3rd instar *P. xylostella* larvae were 32.79 and 11.16 mg/mL, respectively. Regarding stomach toxicity, the LC_{50} values against 3rd instar *M. separate* larvae at 72 h, 96 h, and 120 h were 122.28, 89.33 and 63.47 mg/mL, respectively, and against 3rd instar *P. xylostella* larvae were 1 235.66, 619.16, and 178.85 μg/mL, respectively. For contact activity, *P. chinensis* showed no contact activity against 3rd instar *M. separate* larvae, while the LC_{50} values against 3rd instar *P. xylostella* larvae at 24 h, 48 h, and 72 h were 51.48, 20.52 and 2.06 mg/mL, respectively. [Conclusion] The results indicated that the traditional Chinese medicine *P. chinensis* exhibited stronger insecticidal activity against *P. xylostella* than against *M. separate*, and can be further researched and developed as a botanical insecticide for controlling *P. xylostella*.

Keywords: *Pulsatilla chinensis* (Bge.) Rege, *Mythimna separata* (Walker), *Plutella xylostella* (Linnaeus), Insecticidal activity

收稿日期:2025-03-26　　**修回日期**:2025-06-06
基金项目:山西省重点研发项目子课题(201903D211001-1-7);山西省自然基金项目(20210302123387)
作者简介:王熠(ORCID:0009-0008-1301-9276),讲师,博士,研究方向:植物保护,E-mail:wangyi12334@163.com

白头翁(*Pulsatilla chinensis* (Bge.) Regel)为毛茛科白头翁属多年生药用植物,广泛分布于我国东北和华北等地[1]。白头翁具有抗肿瘤、抗病毒、抗菌、增强免疫功能和保护肝脏等多种药理活性,临床上常用来治疗腹泻、肠炎、细菌性痢疾和结直肠癌等疾病[2-4]。研究表明,毛茛科植物体内的生物碱、原白头翁素等化学成分具有较强的杀虫、抑菌活性[5],在国内常当作土农药和中草药使用[6]。白头翁中的活性成分主要有白头翁素和原白头翁素[5,7-8],具有抑菌、杀虫等多种效果。申晓慧等[9-10]研究发现白头翁氯仿提取物对玉米小斑病、玉米纹枯病、红景天立枯病及玉米弯孢叶斑病具有抑制作用。赵玉婷[11]试验发现白头翁甲醇提取物对人参黑斑病的的EC_{50}为21.58 μg/mL,优于其它提取溶液,且通过破坏细胞膜结构来抑制菌丝生长。吴恭谦等[12]以拟白头翁素为主要成分配制成的农药对小麦赤霉病和水稻白叶枯病都有明显抑制作用。在杀虫方面,乔淑芬等[13]研究发现白头翁乙醇浸提液对大豆荚螟具有触杀作用,LC_{50}为8.63 mg/mL,触杀致死率为96.5%。张明等[14]使用白头翁乙醇提取液处理分月扇舟蛾、舞毒蛾、落叶松毛虫及花布灯蛾后,其校正死亡率分别为65.6%、83.3%、70.0%及56.7%。赵玉敏等[15]研究发现白头翁根部乙醇提取液的浓度为37.50 mg/mL时,对菜青虫的变态率高达99.7%。但有关白头翁对粘虫和小菜蛾的杀虫活性鲜有报道。

粘虫(*Mythimna separata* (Walker))是我国及东亚地区最具破坏性的迁飞性农业害虫,其幼虫暴食性危害玉米、小麦和水稻等主粮作物,2023年被农业农村部列为《一类农作物病虫害名录》首位防控对象,年均造成直接经济损失超50亿元[16]。小菜蛾(*Plutella xylostella* (Linnaeus))是全球范围内危害十字花科作物上最重要的害虫之一,因其繁殖周期短、抗药性强,每年造成全球经济损失超40亿美元,被FAO列为蔬菜生产中的头号防控难题[17]。目前对这2种害虫的防治主要以化学防治为主,但长期的化学农药使用,不仅对生态环境造成破坏,还使粘虫和小菜蛾均产生了抗药性[18-19],而植物源农药可以有效解决化学农药带来的上述问题。

为了挖掘中药白头翁在杀虫方面的应用潜力,本试验以粘虫和小菜蛾作为供试害虫,采用浸渍法、小叶碟添加法以及微量点滴法,测定白头翁乙醇提取物对这2种害虫的杀卵、拒食、胃毒以及触杀活性,明确中药白头翁在杀虫方面的应用价值,为进一步开发该中药资源提供理论依据。

1 材料与方法

1.1 材料

1.1.1 供试中药

中药白头翁干样,安徽亳州药材市场。

1.1.2 供试昆虫

粘虫:虫源来自于山西农业大学植物保护学院养虫室,用新鲜玉米叶('先玉335')饲喂。选取在温度:(25±1) ℃、RH = 60%~80%、L:D = 12 h:12 h的人工气候箱内,粘虫成虫产卵峰期所产的1日龄卵和3龄粘虫幼虫进行试验[20]。

小菜蛾:来自于山西农业大学植物保护学院昆虫神经行为与感官生物学实验室,在养虫室用新鲜甘蓝叶('北方夏帝')连续饲养多代的大小一致、健康的小菜蛾。选取在温度:(25±1) ℃、RH=60%~80%、L:D=14 h:10 h人工气候箱内,小菜蛾成虫产卵峰期所产的1日龄卵和3龄小菜蛾幼虫进行试验[21]。

1.2 试验方法

1.2.1 白头翁乙醇提取物的制备

称取一定质量的中药白头翁干样,按照质量(g):体积(mL)=1:20的比例分三次加入95%乙醇浸泡,用超声波提取3次,每次30 min,合并提取液浓缩得到乙醇提取物,称其重量,计算提取率,提取物放入4 ℃冰箱中保存备用[22]。

提取率=(提取物质量/干样质量)×100%

1.2.2 杀卵活性的测定

采用浸渍法[23-24]进行杀卵活性测定。挑选一定数量1日龄虫卵浸没到不同浓度待测药液中5~10 s后取出,放入培养皿进行培养,每日观察记录卵的孵化情况,计算孵化率,试验重复3次。

1.2.3 拒食和胃毒活性的测定

采用小叶碟添加法[25-26]进行拒食、胃毒活性测定。挑选大小一致健康的3龄幼虫,饥饿4 h后投喂1 cm×1 cm的含有不同浓度待测药液的叶片,每12 h饲喂一次,共投喂4次,每次记录幼虫的取食面积。48 h后,换喂正常叶片,记录72、96及120 h幼虫的死亡情况,计算拒食率、死亡率,试验重复3次。

1.2.4 触杀活性的测定

采用点滴法[27-28]进行触杀活性测定:用微量点滴器将1.0 μL的不同浓度待测药液滴到3龄幼虫的前胸背板上,然后正常饲喂,每隔12 h观察并记录试虫存活情况,连续观察72 h,计算死亡率,试验重复3次。

1.3 数据处理

利用SPSS 17.0与Excel 2010对数据的进行处理和统计分析,并用Duncan氏新复极差法进行处理间的差异显著性检验,显著性水平α=0.05。

2 结果与分析

2.1 白头翁乙醇提取物的制备

白头翁干样为500 g,乙醇提取物的质量为141 g,其提取率为28.2%。

2.2 白头翁对粘虫和小菜蛾的杀卵作用

从表1可以看出,白头翁对粘虫和小菜蛾卵均具有显著的毒杀效果,其不同浓度处理下粘虫卵的孵化率之间存在显著差异(F=854.819;df=6,14;P<0.05),不同浓度处理下小菜蛾卵的孵化率之间也存在显著差异(F=837.279;df=6,14;P<0.05)。随着浓度的降低,粘虫和小菜蛾卵的孵化率显著升高,如100和20 mg/mL下,粘虫卵的孵化率分别为17.33%和93.00%;5和0.5 mg/mL下,小菜蛾卵的孵化率分别为17.33%和93.00%。

表1 白头翁对粘虫和小菜蛾的杀卵活性

Table 1 Ovicidal activity of *P. chinensis* against eggs of *M. separata* and *P. xylostella*

供试害虫 Pest	处理浓度/(mg/mL) Treatment concentration	孵化率/% Hatching rate
粘虫 *M. separata*	20	93.00±1.73a
	30	83.67±0.67b
	40	65.00±1.15c
	60	47.67±1.20d
	80	39.67±0.33e
	90	26.67±0.33f
	100	17.33±0.33g
小菜蛾 *P. xylostella*	0.5	93.00±1.73a
	1	83.67±0.67b
	1.5	65.00±1.15c
	2	56.00±1.00d
	3	36.67±0.88e
	4	27.67±0.33f
	5	17.33±0.33g

注:表中数据为平均数±标准误。同种害虫同列不同字母表示经Duncan氏新复极差法检验差异显著(P<0.05)。

Note: Data are mean±SE. Different letters in the same column of the same pest indicate significant difference at 0.05 level by Duncan's new multiple range test.

白头翁对粘虫有一定的杀卵活性,其LC_{50}值为57.72 mg/mL;对小菜蛾具有较强的杀卵活性,其LC_{50}值为2.22 mg/mL。说明中药白头翁对小菜蛾的杀卵活性显著好于对粘虫卵的(表2)。

表2 白头翁对粘虫和小菜蛾卵的毒力

Table 2 Toxicity of *P. chinensis* against eggs of *M. separata* and *P. xylostella*

供试害虫 Pest	毒力回归方程 Toxicity regression equation	LC_{50}/(mg/mL)	95%置信区间 95% confidence limits	相关系数 r
粘虫 *M. separata*	y=3.237 0x−0.701 4	57.72	53.78~62.49	0.977 8
小菜蛾 *P. xylostella*	y=2.448 2x+4.154 0	2.22	2.03~2.46	0.989 8

2.3 白头翁对粘虫和小菜蛾拒食和胃毒作用

2.3.1 白头翁对粘虫和小菜蛾的拒食作用

从表3可以看出,白头翁可以抑制3龄粘虫幼虫的取食。相同处理时间不同白头翁浓度处理下粘虫幼虫拒食率之间存在显著性差异,如24 h的(F=1 954.27;df=5,12;P<0.05)、48 h的(F=8 309.388;df=5,12;P<0.05)。相同处理时间下,随着白头翁浓度的降低,粘虫的拒食率显著降低,如24 h时,150和25 mg/mL下拒食率分别为84.15%和11.65%。随着处理时间的延长,白头翁对粘虫幼虫的拒食率逐渐升高,如25 mg/mL时,24和48 h的拒食率分别为11.65%和19.12%。

从表4可以看出,白头翁可以显著抑制3龄小菜蛾幼虫的取食。相同处理时间不同浓度处理下小菜蛾幼虫拒食率之间存在显著性差异,如24 h的(F=6 416.765;df=8,18;P<0.05)、48 h的(F=8 895.256;df=8,18;P<0.05)。相同处理时间下,随着白头翁浓度的降低,小菜蛾的拒食率显著降低,如24 h时,80和1 mg/mL下的拒食率分别为89.72%和5.05%。随着处理时间的延长,白头翁对小菜蛾幼虫的拒食率逐渐升高,如40 mg/mL时,24和48 h的拒食率分别为50.53%和70.06%。

表3 白头翁对3龄粘虫幼虫的拒食活性

Table 3 Antifeeding activity of *P. chinensis* against third instar *M. separata*

处理浓度/(mg/mL) Treatment concentration	拒食率/% Antifeeding rate	
	24 h	48 h
25	11.65±0.73f	19.12±0.17f
50	29.51±0.49e	36.56±0.36e
75	43.17±0.16d	52.51±0.31d
110	55.01±0.48c	63.53±0.34c
125	70.13±0.80b	77.44±0.26b
150	84.15±0.71a	88.81±0.22a

注:表中数据为平均数±标准误;同列不同字母表示经Duncan氏新复极差法检验在($P<0.05$)水平差异显著;表4、表6、表8以及表10同。

Note: Data are mean±SE; Different letters in the same column indicate significant difference at 0.05 level by Duncan's new multiple range test; The same as shown in Table 4, Table 6, Table 8 and Table 10.

由表5可见,白头翁对3龄粘虫幼虫具有一定的拒食作用,其24和48 h的AFC_{50}值分别为78.70和63.39 mg/mL。随着处理时间的延长,其拒食活性显著增强。白头翁对3龄小菜蛾幼虫具有较好的拒食作用,其24和48 h的AFC_{50}值分别为32.79和11.16 mg/mL。随着处理时间的延长,其拒食活性显著增强。白头翁对对小菜蛾幼虫的拒食活性显著高于对粘虫幼虫的。

表4 白头翁对3龄小菜蛾幼虫的拒食活性

Table 4 Antifeeding activity of *P. chinensis* against third instar *P. xylostella* larvae

处理浓度/(mg/mL) Treatment concentration	拒食率/% Antifeeding rate	
	24 h	48 h
1	5.05±0.61i	16.18±0.50i
5	11.15±0.61h	32.50±0.45h
10	17.60±0.25g	46.62±0.18g
20	33.80±0.41f	58.60±0.36f
40	50.53±0.40e	70.06±0.27e
50	59.93±0.35d	77.76±0.13d
60	69.86±0.11c	82.29±0.11c
70	78.22±0.12b	89.31±0.09b
80	89.72±0.22a	94.95±0.09a

表5 白头翁对3龄粘虫和小菜蛾幼虫的拒食毒力

Table 5 Antifeeding toxicity of *P. chinensis* against third instar *M. separata* and *P. xylostella* larvae

供试害虫 Pest	处理时间/h Treatment time	毒力回归方程 Toxicity regression equation	AFC_{50}/(mg/mL)	95%置信区间 95% confidence limits	相关系数 r
粘虫	24	y=2.561 3x+0.143 6	78.70	64.67~99.12	0.944 8
M. separata	48	y=2.495 5x+0.504 1	63.39	50.14~79.35	0.937 4
小菜蛾	24	y=1.887 4x+2.139 2	32.79	28.88~37.68	0.971 8
P. xylostella	48	y=1.016 3x+3.935 1	11.16	8.84~14.42	0.986 9

2.3.2 白头翁对粘虫和小菜蛾的胃毒作用

从表6可以看出,白头翁对3龄粘虫幼虫具有一定的胃毒活性。相同处理时间不同中药白头翁浓度处理下的粘虫幼虫死亡率之间存在显著差异,如72 h的($F=70.694$;$df=8,18$;$P<0.05$),96 h的($F=105.107$;$df=8,18$;$P<0.05$)、120 h的($F=83.929$;$df=8,18$;$P<0.05$)。相同处理时间下,随着白头翁浓度的降低,粘虫的死亡率显著降低,如72 h时,250和25 mg/mL下的死亡率分别为86.67%和3.33%。随着处理时间的延长,粘虫幼虫的死亡率逐渐升高,如75 mg/mL时,72、96及120 h的死亡率分别为33.33%、43.33%及56.67%。

白头翁对3龄粘虫幼虫具有一定的胃毒作用,

表6 白头翁对3龄粘虫幼虫的胃毒活性

Table 6 Stomach poison activity of *P. chinensis* against third instar *M. separata*

处理浓度/(mg/mL) Treatment concentration	死亡率/% Mortality rate		
	72 h	96 h	120 h
25	3.33±3.33h	3.33±3.33g	23.33±3.33g
50	13.33±3.33g	16.67±3.33f	36.67±3.33f
60	23.33±3.33f	33.33±3.33e	46.67±3.33e
75	33.33±3.33e	43.33±3.33d	56.67±3.33d
110	46.67±3.33d	56.67±3.33c	63.33±3.33d
125	53.33±3.33d	70.00±0.00b	73.33±3.33c
150	63.33±3.33c	73.33±3.33b	83.33±3.33b
200	73.33±3.33b	83.33±3.33a	100.00±0.00a
250	86.67±3.33a	90.00±0.00a	100.00±0.00a

其72、96及120 h的LC_{50}值分别为112.28、89.33及63.47 mg/mL。随着处理时间的延长,其胃毒活性显著增强(表7)。

表7　白头翁对3龄粘虫幼虫的胃毒毒力

Table 7　Stomach poison toxicity of *P. chinensis* against third instar *M. separata* larvae

处理时间/h Treatment time	毒力回归方程 Toxicity regression equation	LC_{50}/(mg/mL)	95%置信区间 95% confidence limits	相关系数 r
72	y=2.835 6x−0.813 7	112.28	103.44～122.34	0.983 2
96	y=3.283 3x−1.405 9	89.33	83.45～98.61	0.958 0
120	y=2.079 7x+1.251 2	63.47	56.78～71.37	0.957 3

从表8可以看出,白头翁对3龄小菜蛾幼虫具有较强的胃毒活性。相同处理时间不同浓度处理下的小菜蛾幼虫死亡率之间存在显著差异,如72 h的(F=147.587; df=14, 30; P<0.05),96 h的(F=198.143; df=14, 30; P<0.05)、120 h的(F=167.408; df=14, 30; P<0.05)。相同处理时间下,随着白头翁浓度的降低,小菜蛾的死亡率显著降低,如72 h时,2000和500 μg/mL下的死亡率分别为86.67%和6.67%。随着处理时间的延长,小菜蛾幼虫的死亡率显著升高,如在500 μg/mL下,72、96及120 h的死亡率分别为6.67%、40.00%及83.33%。

白头翁对3龄小菜蛾幼虫具有较强的胃毒作用,其72、96及120 h的LC_{50}值分别为1 235.66 μg/mL、619.16及178.85 μg/mL。随着处理时间的延长,其胃毒活性显著增强(表9)。

表8　白头翁对3龄小菜蛾幼虫的胃毒活性

Table 8　Stomach poison activity of *P. chinensis* against third instar *P. xylostella* larvae

处理浓度/(μg/mL) Treatment concentration	死亡率/% Mortality rate		
	72 h	96 h	120 h
50	0.00±0.00i	0.00±0.00i	13.33±3.33i
100	0.00±0.00i	0.00±0.00i	26.67±3.33h
150	0.00±0.00i	6.67±3.33hi	43.33±3.33g
200	0.00±0.00i	13.33±3.33h	56.67±3.33f
300	0.00±0.00i	23.33±3.33g	66.67±3.33e
400	0.00±0.00i	33.33±3.33f	76.67±3.33d
500	6.67±3.33hi	40.00±0.00ef	83.33±3.33c
600	13.33±3.33h	43.33±3.33e	90.00±0.00b
800	23.33±3.33g	56.67±3.33d	100.00±0.00a
1000	33.33±3.33f	70.00±0.00c	100.00±0.00a
1200	43.33±3.33e	76.67±3.33bc	100.00±0.00a
1400	56.67±3.33d	83.33±3.33b	100.00±0.00a
1600	66.67±3.33c	93.33±3.33a	100.00±0.00a
1800	76.67±3.33b	100.00±0.00a	100.00±0.00a
2000	86.67±3.33a	100.00±0.00a	100.00±0.00a

2.4　白头翁对粘虫和小菜蛾的触杀作用

用1～200 mg/mL的白头翁乙醇提取物处理3龄粘虫幼虫时,其24、48及72 h时均未出现死亡,说明白头翁对粘虫幼虫不具有触杀活性。

表10可以看出,白头翁对3龄小菜蛾幼虫具有较强的触杀活性。相同处理时间不同浓度处理下的小菜蛾幼虫死亡率之间存在显著性差异,如24 h的(F=117.615; df=13, 28; P<0.05),48 h的(F=175.863; df=13, 28; P<0.05)、72 h的(F=164.577; df=13, 28; P<0.05)。相同处理时间下,随着白头翁浓度的降低,小菜蛾的死亡率显著降低,如24 h时,80和10 mg/mL下的死亡率分别为73.33%和6.67%。随着处理时间的延长,小菜蛾幼虫的死亡率显著升高,如在20 mg/mL下,24、48及72 h的死亡率分别为13.33%、46.67%及90.00%。

表9　白头翁对3龄小菜蛾幼虫的胃毒毒力

Table 9　Stomach poison toxicity of *P. chinensis* against third instar *P. xylostella* larvae

处理时间/h Treatment time	毒力回归方程 Toxicity regression equation	LC_{50}/(μg/mL)	95%置信区间 95% confidence limits	相关系数 r
72	y=4.587 5x−9.184 2	1 235.66	1 176.43～1 306.48	0.973 6
96	y=2.436 4x−1.801 9	619.16	565.47～687.32	0.986 0
120	y=2.110 2x+0.246 7	178.85	159.91～199.96	0.995 5

表10 白头翁对3龄小菜蛾幼虫的触杀活性

Table 10 Contact poison activity of *P. chinensis* against third instar *P. xylostella* larvae

处理浓度/(mg/mL) Treatment concentration	死亡率/% Mortality rate		
	24 h	48 h	72 h
0.5	0.00±0.00f	0.00±0.00j	16.67±3.33i
1	0.00±0.00f	0.00±0.00j	36.67±3.33h
2	0.00±0.00f	0.00±0.00j	43.33±3.33g
3	0.00±0.00f	3.33±3.33ij	60.00±0.00f
4	0.00±0.00f	10.00±0.00hi	66.67±3.33e
5	0.00±0.00f	16.67±3.33h	73.33±3.33d
10	6.67±3.33ef	33.33±3.33g	83.33±3.33c
20	13.33±3.33e	46.67±3.33f	90.00±0.00b
30	23.33±3.33d	60.00±0.00e	100.00±0.00a
40	36.67±3.33c	66.67±3.33de	100.00±0.00a
50	43.33±3.33c	73.33±3.33cd	100.00±0.00a
60	56.67±3.33b	76.67±3.33bc	100.00±0.00a
70	66.67±3.33a	83.33±3.33b	100.00±0.00a
80	73.33±3.33a	96.67±3.33a	100.00±0.00a

白头翁对3龄小菜蛾幼虫具有较强的触杀作用,其24、48及72 h的LC_{50}值分别为51.48、20.52及2.06 mg/mL。随着处理时间的延长,其触杀活性显著增强(表11)。

3 讨论

从传统中药中寻找和筛选对农业害虫具有杀虫活性的植物资源是开发植物源杀虫剂的重要途径。本研究发现,在杀卵作用方面,中药白头翁对小菜蛾的杀卵活性要显著高于对粘虫的,其LC_{50}分别为2.22和57.72 mg/mL,说明白头翁对小菜蛾具有较强的杀卵活性。但其对小菜蛾的杀卵活性低于宋玉泉等[29]报道的95%丁醚脲原药对小菜蛾的杀卵活性(LC_{50}为11.79 μg/mL)。

在拒食作用方面,白头翁均可以抑制粘虫和小菜蛾的取食,其对小菜蛾的拒食活性显著高于对粘虫的,如48 h时,其AFC_{50}分别为11.16和63.39 mg/mL。白头翁对小菜蛾的48 h拒食活性低于五加皮丙酮提取物(AFC_{50}为4.32 mg/mL)[30]和短序醉鱼草丙酮提取物(AFC_{50}为0.90 mg/mL)的[31]。随着处理时间的延长,白头翁对粘虫和小菜蛾的拒食活性显著提高,这一趋势与其他研究中对粘虫和小菜蛾的拒食作用随时间变化趋势[30-32]基本一致。

在胃毒作用方面,白头翁对小菜蛾幼虫的胃毒活性高于粘虫幼虫,当处理120 h时,其对3龄粘虫幼虫和小菜蛾幼虫的LC_{50}分别为63.47 mg/mL和178.85 μg/mL。白头翁对小菜蛾幼虫的胃毒活性要远高于蛇床子素的[33]和喜旱莲子草不同溶剂提取物的[34],这些药剂72 h的胃毒LC50分别为1235.66μg/mL、515.58 mg/mL(蛇床子素)、45.78 mg/mL(喜旱莲子草石油醚提取物)、22.96 mg/mL(喜旱莲子草氯仿提取物)、101.31 mg/mL(喜旱莲子草乙酸乙酯提取物)、98.20 mg/mL(喜旱莲子草正丁醇提取物)、172.45 mg/mL(喜旱莲子草水提取物)。本试验对粘虫的胃毒活性结果与孙文琰[35]研究结果基本一致,孙文琰发现24和48 h时白头翁对粘虫的胃毒LC_{50}均在96.68 mg/mL以上,本试验中120 h以内的粘虫胃毒LC_{50}均在63.47 mg/mL以上,本试验结果与《中国土农药志》[6]报道的也基本一致(配制毒饵毒杀粘虫的杀虫率为40%),说明白头翁对粘虫具有一定的胃毒活性。

在触杀作用方面,白头翁对粘虫幼虫没有触杀活性,对3龄小菜蛾具有较强的触杀活性。白头翁处理48 h对小菜蛾的触杀活性低于五加皮丙酮提取物[30],其LC_{50}分别为20.52和15.32 mg/mL。但白头翁乙醇提取物处理72 h对小菜蛾的触杀活性高于其对大豆荚螟的[13],其LC_{50}分别为2.06和8.63 mg/mL。白头翁对小菜蛾的触杀和胃毒作用

表11 白头翁对3龄小菜蛾幼虫的触杀毒力

Table 11 Contact poison toxicity of *P. chinensis* against third instar *P. xylostella* larvae

处理时间/h Treatment time	毒力回归方程 Toxicity regression equation	LC_{50}/(mg/mL)	95%置信区间 95% confidence limits	相关系数 *r*
24	y=2.874 5x+0.080 1	51.48	47.47~56.34	0.984 8
48	y=1.548 8x+2.967 8	20.52	17.56~23.78	0.997 4
72	y=1.493 3x+4.531 4	2.06	1.74~2.43	0.972 4

的产生可能是由于白头翁提取物通过小菜蛾的口器和体表,改变了其表皮成分,影响其正常生长[36]。

本试验发现中药白头翁对小菜蛾具有较强的杀虫活性,其作用方式多样,如杀卵、拒食、胃毒及触杀活性,其对小菜蛾幼虫的胃毒作用最为显著。文献报道白头翁的有效成分主要是白头翁素和原白头翁素[5,7-8]。白头翁对小菜蛾的多种杀虫作用方式是否都是由这2种有效成分决定的,有待进一步确认。本试验杀虫作用方式的结果与周琳[37]报道的一致,即与传统植物源农药低浓度为毒杀、高浓度为拒食作用不一样,其原因有待进一步证实。本试验结果与其它有关白头翁杀虫的文献报道的结果都证明白头翁乙醇提取物中含有多种杀虫活性物质,对多种害虫具有较好的杀虫活性[13-15]。同时吴恭谦等[38]也证明以乙醇作为提取溶剂时,白头翁的有效活性成分之一原白头翁素可以稳定存在其中,可以保证白头翁具有杀虫活性。

鉴于原白头翁素稳定性较差和白头翁对小菜蛾作用方式多样这2个原因,今后可以应用白头翁的提取物与其它农药进行复配在小菜蛾全生命周期里对其进行防治。

4　结论

综上,中药白头翁可以作为防治小菜蛾的植物源农药进行进一步研究开发。本试验结果扩展了中药白头翁的杀虫谱,为进一步将中药白头翁开发成植物源杀虫剂奠定了一定的理论基础。

参　考　文　献

[1]李婧实,陈强,郑金双,等.燕山地区白头翁生境土壤化学成分研究[J].安徽农学通报,2023,29(4):146-149,173.
Li J S, Chen Q, Zheng J S, et al. Study on soil nutrients of *Pulsatilla chinensis* ecological environments in the Yanshan Area [J]. Anhui Agricultural Science Bulletin, 2023, 29(4): 146-149, 173.

[2]苏晓悦,徐驰,杜鑫,等.白头翁化学成分及其药理作用研究进展[J].中医药信息,2023,40(3):76-82.
Su X Y, Xu C, Du X, et al. Research progress in chemical constituents and pharmacological effects of *Pulsatilla chinensis* [J]. Information on Traditional Chinese Medicine, 2023, 40(3): 76-82.

[3]Song H H, Xiang Z, Xue S Y, et al. Advances in antitumor effects and mechanisms of *Pulsatilla chinensis* saponins and its monomers [J]. Journal of Chinese Pharmaceutical Sciences, 2021, 30(5): 381-392.

[4]戴小华,吴星霖,王宏军,等.白头翁分步溶剂提取物体外抗菌活性的研究[J].中国饲料,2014,(13):20-21,24.
Dai X H, Wu X L, Wang H J, et al. Study on the antibacterial activity of extracts from *Pulsatilla chinensis* by the step-by-step solvent *in vitro*[J]. China Feed, 2014, (13): 20-21, 24.

[5]周利娟,田延琴,何江涛. 毛茛科植物的农药活性及成分[J].江西农业大学学报,2017,39(2):261-271.
Zhou L J, Tian Y Q, He J T. Pesticidal activities and active ingredients of Ranunculaceae plants [J]. Acta Agriculturae Universitatis Jiangxiensis, 2017, 39(2): 261-271.

[6]中国土农药志编辑委员会.中国土农药志[M].北京:科学出版社,1959:30-40.
Editorial committee of Chinese Original Pesticide. Chinese original pesticides[M]. Beijing: Science Press, 1959: 30-40.

[7]李长玲,蔺娇,栾园园,等.白头翁药理作用研究进展[J].畜牧与饲料科学,2019,40(3):88-91.
Li C L, Lin J, Luan Y Y, et al. Research progress of pharmacological effects of *Pulsatilla chinensis* [J]. Animal Husbandry and Feed Science, 2019, 40(3): 88-91.

[8]朱胄远,杨云,陶莹,等. 原白头翁素的提取合成及保存研究[J]. 中国科技大学学报,1987,17(3):336-342.
Zhu Z Y, Yang Y, Tao Y, et al. Studies on the extraction, synthesis and preservation for protoanemonin [J]. Journal of University of Science and Technology of China, 1987, 17(3): 336-342.

[9]申晓慧,姜成,张敬涛,等. 两种有毒植物提取物的抑菌活性研究[J].作物杂志,2009,(4):35-37.
Shen X H, Jiang C, Zhang J T, et al. Antifungal activity of extracts from two kinds of poisonous plant [J]. Crops, 2009, (4): 35-37.

[10]申晓慧,张敬涛,姜成,等.白头翁3种提取液对玉米小斑病菌的抑制效果[J].作物杂志,2010,134(1):91-93.
Shen X H, Zhang J T, Jiang C, et al. Inhibitory effects of three extracts of *Pulsatilla* on *Bipolaris maydis* [J]. Crops, 2010, 134(1): 91-93.

[11]赵玉婷.藜芦与白头翁有效成分提取工艺的优化及对人参黑斑病菌的抑制效果研究[D].延边:延边大学,2019.
Zhao Y T. Study on the optimization of extraction technology of active components from *Veratrol* and *Pulsatilla chinensis* and its inhibitory effect on A. panax [D]. Yanbian: Yanbian University, 2019.

[12]吴恭谦,张超,王洪,等.拟原白头翁素A防治小麦赤霉病和水稻白叶枯病研究[J].农药,1999,38(10):33-35.
Wu G Q, Zhang C, Wang H, et al. Studies on the control of wheat scab & rice bacterial blight with protoanemonoid A [J]. Pesticides, 1999, 38(10): 33-35.

[13]乔淑芬,于锡钢,顾地周.白头翁不同提取液对大豆荚螟的触杀活性[J].河南农业科学,2009,413(6):105-107.
Qiao S F, Yu X G, Gu D Z. Death activity of extraction from *Pulsatilla chinensis* against *Etiella* zinckenella [J]. Journal of Henan Agricultural Sciences, 2009, 413(6): 105-107.

[14]张明,王威,许铁军,等.8种天然植物粗提物对林木害虫的毒力测定[J].林业科技,2006(2):31-33.
Zhang M, Wang W, Xu T J, et al. Toxicity determination of

the extractions from 8 species plants to forest pests [J]. Forestry science & technology, 2006(2): 31-33.

[15]赵玉敏,顾地周,乔淑芬,等.白头翁不同部位乙醇提取液对菜青虫快速变态的影响[J].吉林农业科学,2014,39(1):56-57,79.
ZhaoY M, Gu D Z, Qiao S F, et al. Influence of rapid transformation of *Pieris rapae* L. by the ethanol extract of different parts of *Pulsatilla chinensis* (Bunge) Regel [J]. Journal of Jilin Agricultural Sciences, 2014, 39(1): 56-57, 79.

[16]江幸福,张蕾,程云霞,等.我国粘虫研究现状及发展趋势[J].应用昆虫学报,2014,51(4):881-889.
Jiang X F, Zhang L, Cheng Y X, et al. Current status and trends in research on the oriental armyworm, *Mythimna separata* (Walker) in China [J]. Chinese Journal of Applied Entomology, 2014, 51(4): 881-889.

[17]常晓丽,袁永达,张天澍,等.小菜蛾生物学特性及防治研究进展[J].上海农业学报,2017,33(5):145-150.
Chang X L, Yuan Y D, Zhang T S, et al. Research progress of the biological characteristics and control of the diamonback moth (*Plutella xylostella*) [J]. Acta Agriculturae Shanghai, 2017, 33(5): 145-150.

[18]Zhao Y Y, Su L, Li S, et al. Insecticide resistance of the field populations of oriental armyworm, *Mythimna separata* (Walker) in Shaanxi and Shanxi Provinces of China [J]. Journal of Integrative Agriculture 2018, 17(7): 1556-1562.

[19]Furlong M J, Wright D J, Dosdall L M. Diamondback moth ecology and management: problems, progress, and prospects [J]. Annual Review of Entomology, 2013, 58: 517-541.

[20]王熠,庞士海,纪薇,等.光周期对黏虫生长发育和生殖的影响[J].植物保护学报,2019,46(3):542-548.
Wang Y, Pang S H, Ji W, et al. Effects of photoperiod on growth, development and reproduction of the oriental armyworm *Mythimna separata* (Lepidoptera: Noctuidae) [J]. Journal of Plant Protection, 2019, 46(3): 542-548.

[21]宋程飞,冯雪梦,王志宇,等.四种非寄主植物精油对小菜蛾的生物活性[J].植物保护学报,2022,49(2):671-682.
Song C F, Feng X M, Wang Z Y, et al. Bioactivities of the essential oils derived from four species of non-host plants against diamondback moth *Plutella xylostella* [J]. Journal of Plant Protection, 2022, 49(2): 671-682.

[22]赵成爱,余梅燕,吴现芳,等.八宝景天乙醇提取物对菜青虫的生物活性[J].农药,2012,51(1):62-63,70.
Zhao C A, Yu M Y, Wu X F, et al. Bioactivity of *Sedum spectabile* boreau extracts against *Pieris rapae* [J]. Agrochemicals, 2012, 51(1): 62-63, 70.

[23]杨帆,望勇,骆海波,等.13种化学杀虫剂对草地贪夜蛾的室内杀卵活性和田间防效[J].江苏农业科学,2022,50(8):37-42.
Yang F, Wang Y, Luo H B, et al. Ovicidal activity and field control efficacy of thirteen chemical insecticides against the *Spodoptera frugiperda* [J]. Jiangsu Agricultural Sciences, 2022, 50(8): 37-42.

[24]赵士文,李梅梅,李伯辽,等.五种药剂对黏虫卵的室内触杀效果及胚胎发育的影响[J].植物保护学报,2019,46(5):1045-1056.
Zhao S W, Li M M, Li B L, et al. Contact toxicity of five insecticides against oriental armyworm eggs and their effects on embryonic development of the armyworm [J]. Journal of Plant Protection, 2019, 46(5): 1045-1056.

[25]Wang Y, Yu X, Zhi X Y, et al. Synthesis and insecticidal activity of novel hydrazone compounds derived from a naturally occurring lignan podophyllotoxin against *Mythimna separata* (Walker) [J]. Bioorganic & Medicinal Chemistry Letters. 2014, 24(12): 2621-2624.

[26]Wang Y, Shao Y H, Wang Y Y, et al. Synthesis and quantitative structure-activity relationship (QSAR) study of novel isoxazoline and oxime derivatives of podophyllotoxin as insecticidal agents [J]. Journal of Agricultural and Food Chemistry, 2012, 60(34): 8435-8443.

[27]吴文君.植物化学保护实验技术导论[M].西安:陕西科学技术出版社,1988,72-77.
Wu W J. Introduction to experimental techniques of plant chemical protection [M]. Xi′an: Shaanxi Scientific and Technical Press, 1988, 72-77.

[28]王晶,张莹,周春相,等.野艾蒿精油化学分离各组分对小菜蛾的杀虫活性[J].吉林农业大学学报,2018,40(6): 675-680.
Wang J, Zhang Y, Zhou C X, et al. Insecticidal activity of different components from *Artemisia lavandulaefolia* essential oil against *Plutella xylostella* [J]. Journal of Jilin Agricultural University, 2018, 40(6): 675-680.

[29]宋玉泉,王军锋,常秀辉.丁醚脲对几种重要害虫的室内生物活性[J].农药,2008,47(8):609-611.
Song Y Q, Wang J F, Chang X H. The bioactivity of diafenthiuron on several important Insects [J]. Agrochemicals, 2008, 47(8): 609-611.

[30]张洁,李雪娇.五加皮丙酮提取物杀虫活性的初步研究[J].西北农业学报,2019,28(11):1906-1912.
Zhang J, Li X J. Study on insecticidal activity of acetone extracts from *Acanthopanar gracilistrylus* [J]. Acta agriculturae boreali-occidentalis sinica, 2019, 28(11): 1906-1912.

[31]刘彦超,田进,黑育荣.短序醉鱼草提取物对3种鳞翅目昆虫杀虫活性研究[J].安徽农业科学,2020,48(1):150-153,169.
Liu Y C, Tian J, Hei Y R. Study on Insecticidal Activities of *Buddleja brachystachya* Diels.on three Lepidoptera Insects [J]. Journal of Anhui Agricultural Sciences, 2020, 48(1): 150-153, 169.

[32]郭生虎,王敬东,马洪爱.伏毛铁棒锤生物总碱的杀虫活性研究[J].中国农学通报,2013,29(36):382-385.
Guo S H, Wang J D, Ma H A. Insecticidal activity of total alkaloid from *Aconitum flavum* [J]. Chinese Agricultural Science Bulletin, 2013, 29(36): 382-385.

[33]孟琳琳,王进忠,张志勇,等.蛇床子素对小菜蛾幼虫的胃毒作用及对虫体内两种酶活性的影响[J].北京农学院学报,2010,25(3):24-27.
Meng L L, Wang J Z, Zhang Z Y, et al. Stomach action of osthole and its effect on two enzyme activities of *Plutella*

xylostella larvae [J]. Journal of Beijing University of Agriculture, 2010, 25(3): 24-27.

[34]李丹,张震,王育鹏,等.喜旱莲子草提取物的杀虫活性[J].生物安全学报,2015,24(1):57-63.
Li D, Zhang Z, Wang Y P, et al. Insecticidal activity of extracts from the invasive alien plant, *Alternanthera philoxeroides*, against two kinds of pests [J]. Journal of Biosafety, 2015, 24(1): 57-63.

[35]孙文琰.24种植物对棉铃虫、粘虫杀虫活性的研究[D].保定:河北农业大学,2008.
Sun W Y. The Study on insecticidal activity of 24 species of plant against *Helicoverpa armigera* and armyworm [D]. Baoding: Hebei Agricultural University, 2008.

[36]Verma G S, Ramakrishnan V, Mulchandani N B, et al. Insect feeding deterrents from the medicinal plant *Tylophora asthmatica* [J]. Entomologia Experimentalis et Applicata, 1986, 40(1): 99-101.

[37]周琳,冯俊涛,马志卿,等.雷公藤总生物碱对粘虫的生物活性[J].植物保护学报,2006,33(4):401-406.
Zhou L, Feng J T, Ma Z Q, et al. Insectical activity of total alkaloid from *Tripterygium wilffordii* Hook against *Mythimna separata* (Walker) (Lepidoptera: Noctuidae) [J]. Journal of Plant Protection, 2006, 33(4): 401-406.

[38]吴恭谦,张超,伍越环.三种毛茛科植物提取物及原白头翁素的活性研究[J].安徽农学院学报,1989(1):21-31.
Wu G Q, Zhang C, Wu Y H. Studies on the extracts of three Ranunculaceae species and Protoanemonin for bioassays[J]. Journal of Anhui Agricultural University, 1989(1): 21-31.

(编辑:吕俊俐)