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生态学报

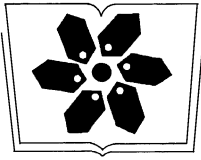
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(SHENGTAI XUEBAO)

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封面图说: 气候变暖下的北极冰盖——自从 1978 年人类对北极冰盖进行遥感监测以来, 北极冰正以平均每年 8.5% 的速度持续缩小, 每年 1500 亿吨的速度在融化。这使科学家相信, 冰盖缩小的根本原因是全球变暖。北极的冰盖消失, 让更大面积的深色海水暴露出来, 使海水吸收更多太阳热辐射反过来又加剧冰盖融化。由于北极冰的加速融化, 北冰洋的通航已经成为 21 世纪初全球最重要的自然地理事件和生态事件。从这张航片可以看到北极冰缘正在消融、开裂崩塌的现状。

彩图提供: 陈建伟教授 北京林业大学 E-mail: cites.chenjw@163.com

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陈宇,傅强,赖凤香,罗举,张志涛,胡国文. 水稻生育期对褐飞虱和白背飞虱卵巢发育及起飞行为的影响. 生态学报, 2012, 32(5): 1546-1552.

Chen Y, Fu Q, Lai F X, Luo J, Zhang Z T, Hu G W. The effects of rice growth stages on the ovarian development and take-off of *Nilaparvata lugens* and *Sogatella furcifera*. Acta Ecologica Sinica, 2012, 32(5): 1546-1552.

水稻生育期对褐飞虱和白背飞虱 卵巢发育及起飞行为的影响

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摘要: 研究了取食分蘖初期、拔节期和孕穗抽穗期稻株上的褐飞虱和白背飞虱成虫的卵巢发育和起飞情况。其中,水稻生育期对褐飞虱的影响相对较小,不同生育期稻株上试虫的卵巢发育级别羽化后的 4d 内均无显著差异,羽化后第 5 天的褐飞虱在孕穗抽穗期卵巢发育最快,分蘖初期最慢,拔节期居中。褐飞虱的起飞率在各个生育期均无显著差异。白背飞虱卵巢发育、起飞率均受水稻生育期的显著影响,在水稻分蘖初期,卵巢发育最快,孕穗抽穗期则卵巢发育最慢,拔节期居中,水稻分蘖初期,起飞率最低,孕穗抽穗期起飞率最高,拔节期居中。结果表明,水稻生育期对两种飞虱卵巢发育和起飞行为的影响明显不同。认为水稻生育期对两种飞虱卵巢发育与起飞行为的不同影响,应是水稻田间白背飞虱发生较早、褐飞虱发生较晚的一个重要原因。

关键词: 水稻;生育期;褐飞虱;白背飞虱;卵巢级别;起飞

The effects of rice growth stages on the ovarian development and take-off of *Nilaparvata lugens* and *Sogatella furcifera*

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Abstract: The brown planthopper (*Nilaparvata lugens* (Stål)) and white-backed planthopper (*Sogatella furcifera* (Horváth)) represent two of the most important insect pests of rice in Asia, causing severe damage to rice production. Both belong to long-distance migratory insects but differ in the time when they reach maximum density during rice-growing season. *S. furcifera* generally reaches its peak of occurrence when rice is before the filling stage; while *N. lugens* reaches its peak at the rice filling stage. It is possible that the same rice stage might impact the two planthopper species differently, thus leading to such a seasonal difference in population growth. To test this, we inoculated newly-emerged adults onto rice plants at each of the three developmental stages, i. e., early tillering stage (about 40-d old, with 2—3 tillers), jointing stage (about 60-d old, the longest internode < 2 cm) and booting-to-heading stage (about 75-80-d old). The level of ovarian development and take-off rate were then measured daily from the 2nd to the 5th day and from the 1st to the 5th day after emergency, respectively. Ovarian development from 2nd to the 5th day was largely dominated by grade I, II, III and IV, respectively, with three exceptions including the 4d- (dominated by grade II) and 5d-old *S. furcifera* females (grade III) at booting-to-heading stage plants, plus the 5d-old *S. furcifera* females (grade III) at jointing stage plants. For ovarian development in *N. lugens* females, in vast majority of the cases the three rice stages showed comparable proportion of females at each of the detected ovarian development grades, we only observed significant difference between early tillering

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stage (73.2% of the females at grade IV) and booting-to-heading stage (89% at grade IV) on the 5th day. In contrast, the grade of ovarian development displayed much larger differences among the three rice stages for both 4d- and 5d-old *S. furcifera* females. In particular, over 86% of the females from rice early tillering stage developed into grade III on the 4th day and into grade IV on the 5th day, versus less than one quarter of the females from the booting-to-heading stage. To a similar extent, the ratio of females at grade III was 4.2:1 between jointing stage and booting-to-heading stage on the 4th day, along with a ratio of up to 6.8:1 between early tillering stage and jointing stage for the 5d-old females at grade IV. As for the take-off rate, while little variation was seen for *N. lugens* across the three rice stages, noticeable differences were revealed for 1d-, 4d- and 5d-old *S. furcifera* adults, with early tillering stage being constantly associated with the lowest take-off rate and booting-to-heading stage with the highest take-off rate. Thus, our results demonstrated a profound effect on the development of *S. furcifera* by a change of rice stage, as compared to relatively limited effect on *N. lugens* development. Furthermore, among the three rice stages, early tillering stage is most favorable and booting-to-heading stage is least favorable for *S. furcifera* development, a trend appearing to be reversed in *N. lugens*. Taken together, our analysis offers a plausible explanation for why the peak of *S. furcifera* comes before that of *N. lugens*.

Key Words: Rice; Growth stage; *Nilaparvata lugens*; *Sogatella furcifera*; Ovarian development grade; Take-off behavior.

水稻是世界上最主要的粮食作物,全球约有 30 亿人以稻米为主食。20 世纪 70 年代以来,稻飞虱开始成为我国华南及长江流域等地水稻生产上的主要害虫,近年来更是连续大发生,给水稻生产造成了严重损失^[1-4]。褐飞虱 *Nilaparvata lugens* (Stål)、白背飞虱 *Sogatella furcifera* (Horvath) 是我国水稻上两种最主要的稻飞虱,具远距离迁飞习性;我国除华南南部等少量地区可终年繁殖外,其他地区每年的初始虫源均由南方迁飞而来,一般每年春季随西南气流从中南半岛迁入华南及西南南部繁殖为害,夏季再随西南或偏南气流向北迁飞,秋季则随东北气流回迁^[5-10]。

在田间发生时间上,白背飞虱一般早于褐飞虱。就长江中下游流域稻区而言,7 月—9 月上旬的稻飞虱以白背飞虱为主,9 月中旬—10 月则以褐飞虱居优^[8, 11-12]。尽管我国白背飞虱每年的迁入早于褐飞虱,但两种飞虱在田间发生时间上的差异可能并不仅仅由迁入期所决定。在两种飞虱终年繁殖地区(如越南中北部),白背飞虱的发生为害期亦早于褐飞虱,其中,白背飞虱一般发生在水稻生长前期,进入穗期后迁出;而褐飞虱则多发生在水稻生长后期,水稻成熟时迁出。两种飞虱发生时间上的差异是否还与水稻生育期有关?目前尚未见相关报道。

迁飞昆虫的迁飞时雌虫的卵巢尚未发育成熟^[13-14]。研究表明,褐飞虱和白背飞虱雌虫的迁飞发生在卵巢发育级别 II 级以前^[4, 6, 14-15]。基于此,本研究就不同生育期水稻上饲养的两种飞虱成虫的卵巢发育进度与起飞行为进行观察,旨在揭示不同生育期水稻与两种飞虱迁飞行为的关系。

1 材料与方 法

1.1 供试水稻

感虫水稻品种 TN1 分期播种,种植于无虫网室的水泥池中,培植至分蘖初期(约 40d 秧龄,2—3 个分蘖)、拔节期(约 60d 秧龄,最长节间距离<2 cm)、孕穗抽穗期(约 75—80 d 秧龄)等 3 个生育期用于本试验。

接虫前 5—7d,选择各生育期稻苗移栽于泥钵(直径 12 cm,高 15 cm),每钵保留 10—12 株分蘖,清洗后放置于防虫笼罩中待稻苗成活后备用。接虫前转移到养虫笼(长×宽×高为 75 cm×60 cm×90 cm)中,每笼放置 4 盆稻苗。

1.2 供试虫源与试虫处理

褐飞虱、白背飞虱均为中国水稻研究所富阳基地用感虫品种 TN1 稻苗饲养的实验种群。吸取适量的初孵化 1 龄若虫(孵化后 24 h 内)接于有不同生育期 TN1 稻苗的养虫笼中,接虫后第 7 天更换 1 次相应生育期的稻苗,以确保饲养期间每个养虫笼中的稻苗符合 3 个生育期设置要求,并能获得足够的长翅型成虫供试验

所用。成虫开始羽化后,吸取羽化当天的长翅成虫饲养于放置有相应生育期稻株的养虫笼(长×宽×高为 60 cm×60 cm×100cm,40 目尼龙纱)中,每笼接同一天羽化的同一处理成虫约 100 头。

1.3 试虫卵巢发育与起飞行为观察

羽化后第 1(羽化当天)、2、3、4、5 天傍晚(日落后约半小时)观察养虫笼顶、侧壁上的虫数,将这些飞虱视为“试图起飞”的个体,计算起飞试虫比例。

取羽化后第 2、3、4、5 天的雌虫,按照王家银等^[16]的方法解剖雌虫,并参照吴荣宗^[17]的方法确定试虫的卵巢发育级别,每处理重复 5—7 次,每重复解剖约 10 头雌虫。

试验在室内条件下进行,平均室内温度(28 ± 2)℃,室内自然光照。

1.4 数据分析

利用唐启义和冯明光^[18]的 DPS 数据处理软件对各试验参数进行方差分析,并采用 Duncan 氏新复极差法进行多重比较,其中多因素方差分析采用一般线性模型(GLM)进行。

2 结果与分析

2.1 水稻生育期对羽化后不同日龄雌虫卵巢发育的影响

对雌虫各级别卵巢所占比例进行飞虱种类(褐飞虱和白背飞虱)、水稻生育期(分蘖初期、拔节期、孕穗抽穗期)的双因素方差分析(表 1),结果表明,飞虱种类、水稻生育期及二者的交互作用对雌虫卵巢发育的影响主要体现在羽化后第 4、5 天($P < 0.05$),而在羽化后 2、3d 均无显著影响($P > 0.05$)。

就羽化后不同时期两种飞虱的总体卵巢发育情况来看:羽化后第 2、3、4 天,两种飞虱的优势卵巢发育级别分别为 I 级、II 级、III 级;羽化后第 5 天,白背飞虱为 III 级,褐飞虱为 IV 级。两种飞虱相比,褐飞虱的卵巢发育相对快于白背飞虱,这种差异在羽化后第 4、5 天达到显著水平(表 1、图 1)。

表 1 飞虱种类、水稻生育期对稻飞虱卵巢发育的影响的双因素方差分析(P 值)

Table 1 Two-way ANOVA for the effects of planthopper species and rice growth stages on ovarian development of females (P-value)

考察指标 Index studied		飞虱种类 Planthopper species (A)	水稻生育期 Rice growth stages (B)	交互作用 Interaction (A×B)
羽化后 2 d 卵巢级别 Ovarian development grade at two day after emergence	I 级 Grade I	0.055	0.866	0.515
	II 级 Grade II	0.055	0.866	0.515
羽化后 3 d 卵巢级别 Ovarian development grade at three days after emergence	I 级 Grade I	0.147	0.764	0.366
	II 级 Grade II	0.343	0.315	0.400
	III 级 Grade III	0.418	0.703	0.076
羽化后 4 d 卵巢级别 Ovarian development grade at four days after emergence	I 级 Grade I	0.364	0.438	0.438
	II 级 Grade II	0.000	0.000	0.000
	III 级 Grade III	0.004	0.000	0.000
	IV 级 Grade IV	0.001	0.712	0.907
羽化后 5 d 卵巢级别 Ovarian development grade at five days after emergence	II 级 Grade II	0.030	0.048	0.048
	III 级 Grade III	0.000	0.000	0.000
	IV 级 Grade IV	0.000	0.000	0.000

水稻生育期对两种飞虱卵巢发育的影响亦不相同(图 2)。3 个水稻生育期上的褐飞虱直到羽化后第 5 天才表现为显著差异,且以分蘖初期卵巢发育最慢,其 III 级卵巢比例显著高于拔节期与孕穗抽穗期,相差 11—16 个百分点;而 IV 级卵巢比例则显著低于后两个生育期,相差 11—17 个百分点。白背飞虱则从羽化后第 4 天开始有明显差异,其中羽化后第 4 天水稻分蘖初期与拔节期上的卵巢发育显著快于孕穗抽穗期,且前两个生育期间无显著差异;前两个生育期的 II 级卵巢低于孕穗抽穗期 66—70 个百分点,III 级卵巢则高 65—69 个百分点;羽化后第 5 天水稻分蘖初期上的卵巢则显著快于拔节期与孕穗抽穗期,且后两者间无显著差异,前一个生育期的 III 级卵巢低于后两者 63—71 个百分点,IV 级卵巢高 75—86 个百分点。

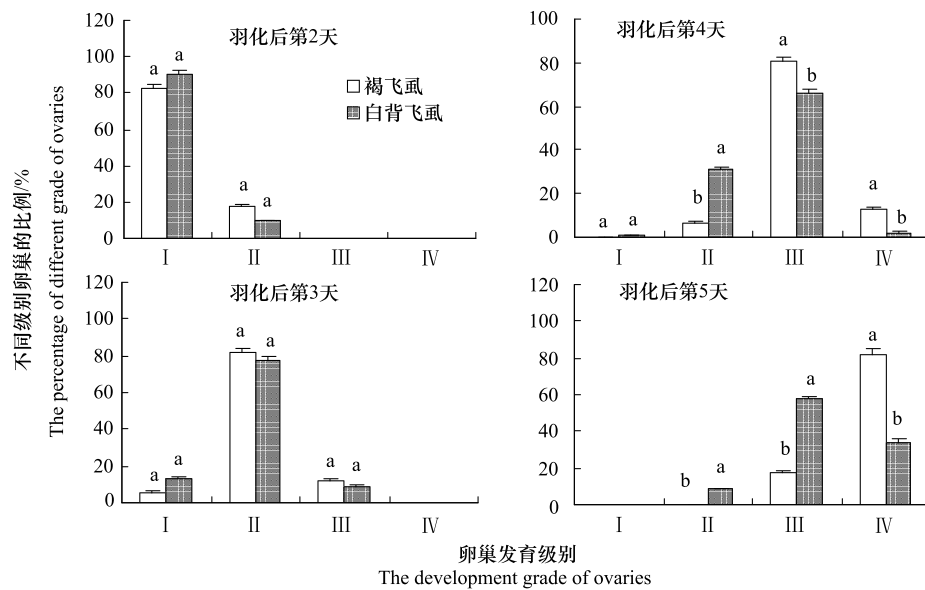


图1 羽化后不同时期褐飞虱和白背飞虱雌虫的卵巢发育情况比较(平均值±标准误)

Fig. 1 Comparison of the ovary development of *N. lugens* and *S. furcifera* at different days after emergency (mean ± SE)

同一卵巢发育级别两种飞虱柱图上方具相同字母者示无显著差异($P>0.05$)

综上所述,水稻生育期对褐飞虱雌虫卵巢发育的影响相对较小,且水稻中后期(拔节期、孕穗抽穗期)比水稻早期(分蘖初期)更适于其卵巢发育;而水稻生育期对白背飞虱卵巢发育的影响相对较大,且其影响与褐飞虱情况相反,水稻分蘖初期卵巢发育最快,拔节期次之,孕穗抽穗期再次之。

2.2 水稻生育期对羽化后不同时间长翅试虫起飞的影响

对试虫起飞率进行飞虱种类、水稻生育期与羽化后不同天数的三因素方差分析结果表明,飞虱种类($F=41.72$, $df=1$, $P<0.001$)、水稻生育期($F=7.28$, $df=2$, $P=0.001$)、羽化后天数($F=11.93$, $df=4$, $P<0.001$)及飞虱种类×羽化后天数交互作用($F=3.21$, $df=4$, $P=0.015$)、飞虱种类×水稻生育期($F=6.75$, $df=2$, $P=0.002$)均对试虫的起飞有极显著影响;水稻生育期×羽化后天数、飞虱种类×水稻生育期×羽化后天数等交互作用对稻飞虱起飞行为影响不显著($P>0.05$)。

两种飞虱间,起飞率总体上差异显著(图3),白背飞虱是褐飞虱的2.1倍。水稻生育期间,孕穗抽穗期起飞比例最高,显著高于前两个生育期(图3)。就羽化后不同天数而言,羽化后第2、3天为起飞高峰期;羽化后第2天起飞率最高,是第5天最低起飞率的3.1倍。

就水稻生育期对两种飞虱起飞行为的具体影响来看(图4),3个水稻生育期上的褐飞虱起飞率无显著差异;白背飞虱则不同,羽化后第1、4、5天不同生育期稻株上的试虫起飞率有明显差异,且羽化后各时间均以分蘖初期试虫的起飞率最低,孕穗抽穗期最高(仅羽化后第3天例外)。显然,水稻生育期对褐飞虱起飞行为的影响相对较小,而对白背飞虱起飞率的影响相对较大,白背飞虱在分蘖初期起飞较少,而在孕穗抽穗期起飞较多。

3 讨论

田间白背飞虱早于褐飞虱发生可能与多种因素有关。前人研究表明,我国长江中下游等褐飞虱和白背飞虱不能越冬的区域,白背飞虱每年的初始迁入时间一般早于褐飞虱^[5-6];白背飞虱的发育速率相对较快,世代发育历期短于褐飞虱;两种飞虱对温度的适应性不同,其中白背飞虱的生长适温范围(15—30℃)宽于褐飞虱(20—30℃)^[19],这些均可能导致白背飞虱的发生早于褐飞虱。两种飞虱还表现出不同的密度效应,褐飞虱的种内密度效应弱于白背飞虱^[20-21];褐飞虱的长翅成虫比例对种间效应的敏感性高于对种内密度效应,而白背飞虱则反之,种间效应弱于种内效应^[22]。

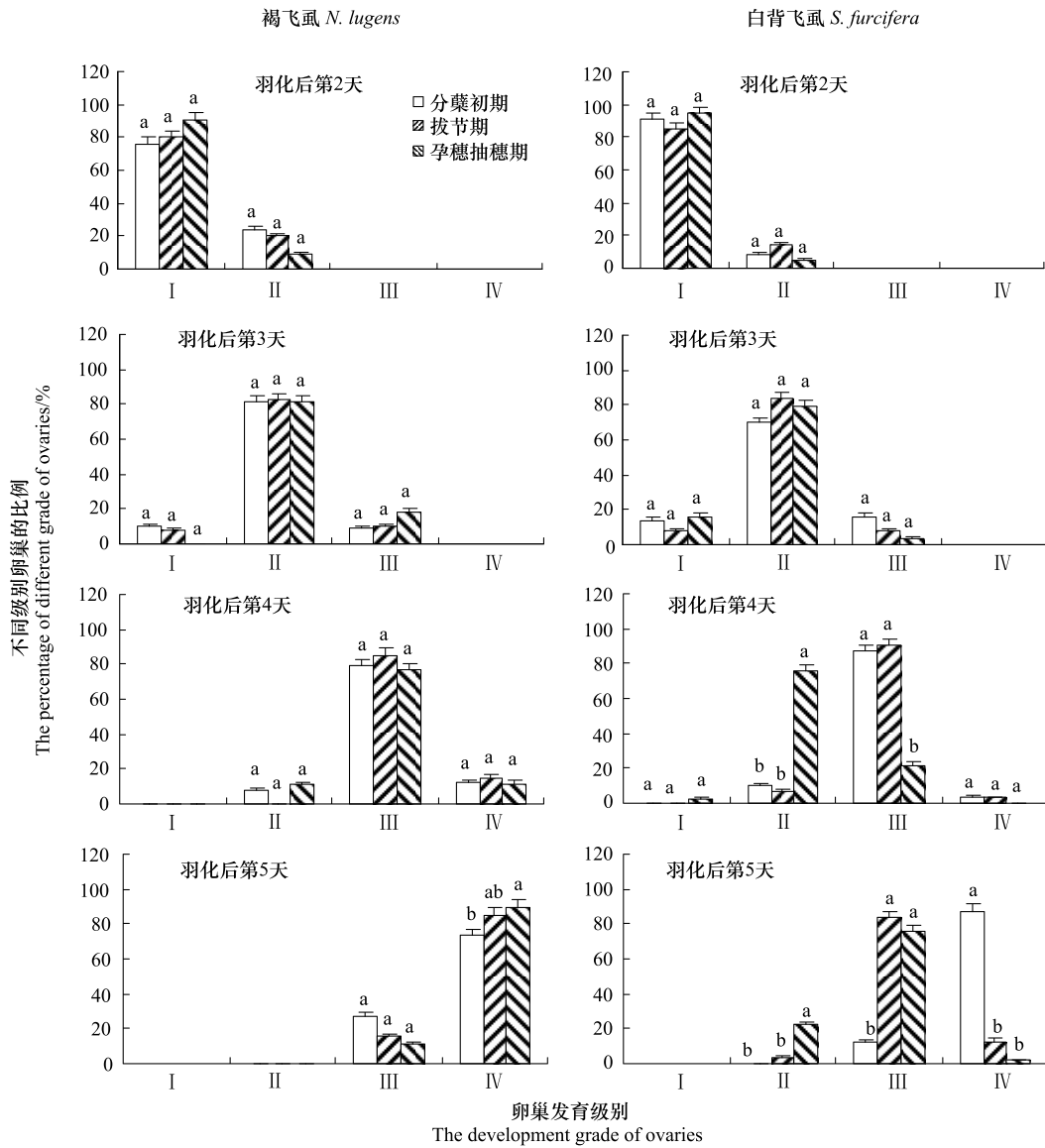


图2 羽化后不同时期两种飞虱在三个生育期水稻上的雌虫卵巢发育情况(平均值±标准误)

Fig.2 Ovarian development of the two planthoppers with different ages after emergency in three rice growth stages (mean±SE)

同一卵巢发育级别不同处理柱图上方具相同字母者示在5%水平下无显著差异

本研究发现水稻生育期对褐飞虱和白背飞虱成虫卵巢发育与起飞行为的影响明显不同。其中,水稻生育期对褐飞虱的影响相对较小,仅羽化后第5天卵巢发育有显著差异,水稻早期(分蘖初期)卵巢发育最慢,后期(孕穗抽穗期)卵巢发育最快;而对白背飞虱的影响相对明显,卵巢发育与起飞均受显著影响,且水稻早期卵巢发育最快,起飞率最低,水稻后期卵巢发育最慢,起飞率最高。可以认为,不同生育期水稻上两种飞虱成虫卵巢发育与起飞行为的差异应该是田间白背飞虱的发生早于褐飞虱的一个重要原因。前人的研究亦发现白背飞虱受到水稻生育期的明显影响,其迁入成虫喜选择分蘖期水稻,迁入后后代的长翅型比例与水稻生育期正相关,大约至孕穗期前10d达100%^[23]。

褐飞虱、白背飞虱雌虫的迁飞一般发生在卵巢发育Ⅱ级以前的幼嫩阶段^[11-12],随着羽化后天数的增加卵巢级别增加,起飞比例明显下降^[24]。本研究中,褐飞虱和白背飞虱起飞高峰期发生在羽化后第2—3天,此时雌虫的优势卵巢发育级别分别在Ⅰ级和Ⅱ级(图1),进一步反映出飞虱起飞与卵巢发育关系密切。这种关系还可以从不同生育期水稻上飞虱起飞与卵巢发育进度的关系得到印证。孕穗抽穗期稻苗上白背飞虱的卵巢

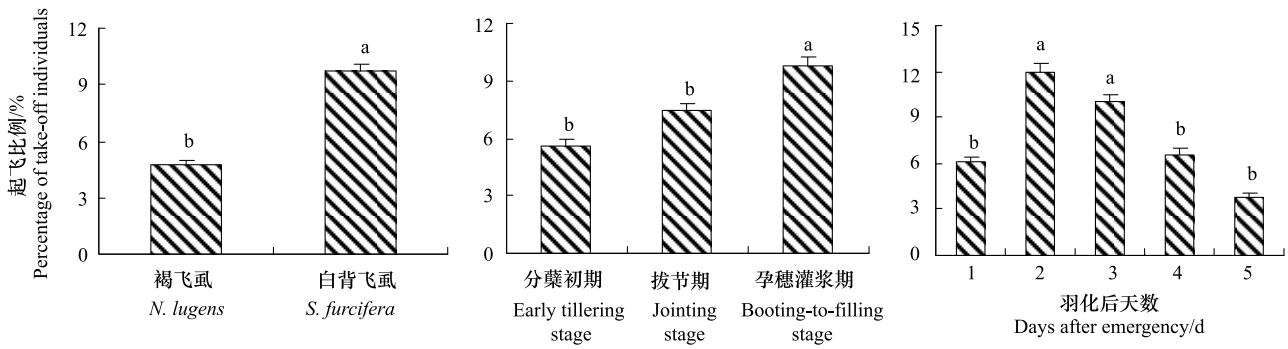


图 3 不同飞虱种类、水稻生育期及羽化后日龄试虫的起飞情况(平均值±标准误)

Fig. 3 The take-off behavior of insects tested for different planthopper species, rice growth stages and days after emergency (mean±SE)

不同处理柱图上方具相同字母者示在 5% 水平下无显著差异 ($P>0.05$)

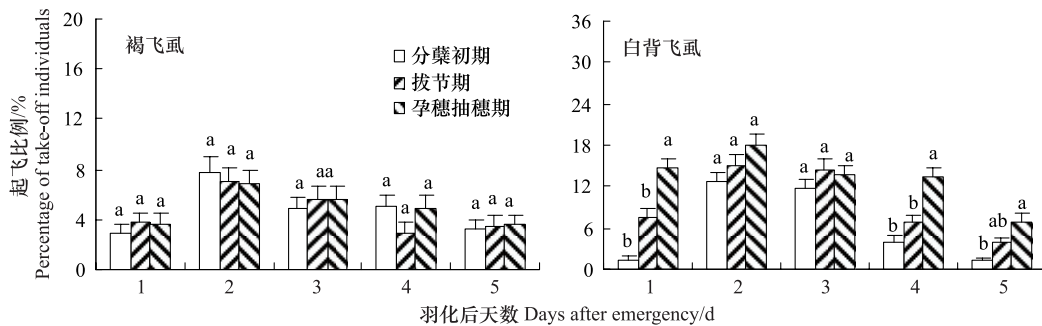


图 4 3 个生育期稻苗上两种飞虱羽化后不同日龄试虫的起飞情况(平均值±标准误)

Fig. 4 Take-off rate of two planthoppers in different days after emergency at three rice growth stages (mean ± SE)

不同水稻生育期柱图上方具相同字母者示在 5% 水平下无显著差异

发育较慢,直到羽化后第 4 天仍以 II 级卵巢为主(图 2),其起飞率则从羽化后直到第 4 天均维持在较高水平(图 4);而白背飞虱卵巢发育较快的水稻分蘖初期、拔节期试虫卵巢在羽化后第 4 天多达 III 级,其起飞率亦随之迅速降低。

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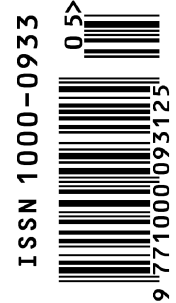
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