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Effects of Cowpea-cucumber Intercropping on *Lampides boeticus* (Lepidoptera: Lycaenidae) Infestation, Crop Yield and Land Equivalent Ratio

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ABSTRACT

Background: The study aimed to move away from the use of pesticides by growing cowpeas and cucumbers together to identify the extent to which it is possible to disrupt the behavior of the insect *Lampides boeticus* in infesting the two crops as a method of integrated management. to evaluate cowpea-cucumber intercropping under practical IPM field conditions in relation to *Lampides boeticus* infestation severity, the yields of both component crops and the land equivalent ratio (LER).

Methods: Five cropping systems were compared in a randomised complete block design (RCBD) with four replications: Sole cowpea (T_1), sole cucumber (T_2) and three intercropping row arrangements (1:1, 2:1 and 1:2 cowpea: cucumber; T_3, T_4 and T_5, respectively). Under the tested field-management conditions, all intercropping systems were associated with significantly lower larval density, pod infestation, holes per pod and damaged-seed proportion than sole cowpea ($p \leq 0.05$).

Result: Pod infestation declined from 48.0% under sole cowpea to 31.0-37.0% under intercropping. Despite reductions in individual crop yields, all intercropping systems achieved total LER values of 1.51-1.56, confirming a land-use advantage over sole cropping. The 1:1 (T_3) and 1:2 (T_5) arrangements offered the most favourable balance between pest suppression and land-use efficiency. These results support cowpea-cucumber intercropping as an IPM-compatible cropping strategy for *Lampides boeticus* in Diyala Governorate, while future pesticide-free or factorial trials are needed to isolate the independent effect of crop arrangement from associated field-management practices.

Key words: Cowpea, Integrated pest management, Intercropping, *Lampides boeticus*, Land equivalent ratio.

INTRODUCTION

Legume and vegetable crops are fundamental components of human diets in many developing countries, supplying protein, vitamins and minerals while also contributing to soil fertility through biological nitrogen fixation (Jackai and Daoust 1986; Oyewale and Bamaiyi 2013). Cowpea [*Vigna unguiculata* (L.) Walp.] (Fabaceae) is widely cultivated in hot, semi-arid regions as both a grain legume and a vegetable, whereas cucumber (*Cucumis sativus* L.) (Fabaceae) ranks among the most economically important cucurbit crops globally in terms of cultivated area and consumption (Dimande *et al.* 2024; Jackai and Daoust, 1986; Oyewale and Bamaiyi, 2013).

Insect pests cause huge losses to crops. The infestation of the pea blue butterfly, *Lampides boeticus* (Linnaeus) (Lepidoptera: Lycaenidae) on cowpeas, for example, is severe. *L. boeticus* females lays her eggs on buds and young pods. The larvae then feed on the floral tissues and the seeds and complete the life cycle during pod and seed formation. This causes the plant to shed its pods. The seed damage is also severe. *L. boeticus* is active in Iraq when the cowpeas are in the pod and floral stages of growth. The peaks of *L. boeticus* population also coincide with the cowpea flowering and pod filling stages. Khidher (2024) reported that there were varietal differences in susceptibility and this shows that the choice of cultivars may affect the balance of the ecosystem, which is the focus of integrated pest management (IPM). Cucumber, similar to cowpea, is also susceptible to pests that cause economic loss from yield and quality. These insects include aphids, whiteflies, cucumber beetle and spider mite (FAO, 2018; Dimande *et al.,* 2024; Sharvan *et al.,* 2025).

Intercropping, which involves multiple crops cultivated on the same land in the same season, enhances the

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efficient use of light, water and nutrients, increases overall productivity and reduces economic risk. Several studies on cowpea-based intercropping have reported land equivalent ratio (LER) values greater than 1.0, indicating an advantage in public yield compared to sole cropping. Intercropping also alters canopy architecture, decreases host-plant homogeneity and increases the activity levels of natural enemies, thereby resulting in reduced pest populations. In the aspect of cucumber growing with cowpea as intercrop, cucumber is an economic crop in the Diyala Governorate (approximately 33°34′N, 44°32′E) and thus this intercropping system offers both economic and agronomic benefits to local smallholder farmers. In view of the effects caused by pest control using pesticides, an urgent need has emerged to follow different methods of pest management that are eco-friendly (Al-Hayali and Qader 2024; Al-Hayali and AL-Zuhairi, 2024; Al-Hayali *et al.,* 2025; Al-Hayali *et al.,* 2026). This is due to the fact it as it cucumber is not a host of *L. boeticus* and its wide, prostrate canopy is very different from the erect nature of cowpea and may disrupt the behavior of *L. boeticus*. The purpose of the study is to move away from the use of pesticides by cultivating cowpeas and cucumbers together to identify the extent to which it is possible to disrupt the behavior of the insect *L. boeticus* in infecting the two crops as a method of integrated pest management among cooperative farmers in Diyala Governorate.

MATERIALS AND METHODS

Experimental site

The pea blue butterfly, *L. boeticus* (Linnaeus) (Lepidoptera: Lycaenidae), is a key pest of cowpea that inflicts severe damage to pods and seeds during the flowering and pod-filling stages. A field experiment was conducted during the spring 2025 season at Khan Bani Saad, Diyala Governorate, Iraq. The region in the field experiment is north of the Baqubah District (approximately 33°34′N, 44°32′E) located in Iraq, the summer months are hot and dry, with average temperatures commonly ranging from 34 to 38°C during the crop-growing period and the winters are mild, with average temperatures of about 10 to 15°C with an extremely low precipitation of 200 to 250 mm annual that will fall primarily during the winter months. Farmers in this area also endorse clay loam, moderately fertile in texture coupled with good internal drainage.

Experimental design and treatments

A randomized complete block design (RCBD) with four replications was used. Five cropping systems were evaluated: T_1, sole cowpea; T_2, sole cucumber; T_3, 1:1 intercropping (alternating cowpea and cucumber rows); T_4, 2:1 intercropping (two cowpea rows followed by one cucumber row); and T_5, 1:2 intercropping (one cowpea row followed by two cucumber rows). Each plot comprised six rows of 4 m length. Row spacing was 60 cm and within-row plant spacing was 25 cm for both crops. The net plot area was approximately 14.4 m^2. Guard alleys were maintained between adjacent plots and blocks to minimize inter-plot interference.

Crop management

The field was prepared by deep ploughing with a disc plough, followed by secondary tillage and levelling. Seeds of locally grown cowpea and cucumber varieties were hand-sown at 2-3 seeds per hill and thinned to one plant per hill after establishment. Phosphorus was applied as single superphosphate (≈15.5% P_2O_5) at 80 kg P_2O_5 ha^{-1} before sowing and potassium was supplied as potassium sulphate (≈50% K_2O) at 60 kg K_2O ha^{-1} before sowing. Nitrogen was applied as urea (46% N) at a total rate of 80 kg N ha^{-1}, split equally between applications at 20 and 40 days after emergence. Furrow irrigation was applied every 7-8 days during March-April and every 5-6 days during May-June, adjusted to prevailing weather conditions, particularly during flowering and pod/fruit set. Weeds were controlled by hand hoeing as required.

No insecticides were applied directly to cowpea rows throughout the experiment in order to allow the natural development of *L. boeticus* infestation and to assess the potential pest-suppression effect of the intercropping arrangements. In cucumber-containing treatments (T_2, T_3, T_4 and T_5), one foliar application of deltamethrin (2.5% EC, @ 0.5 L ha^{-1}) was applied at Week 6 after sowing only to cucumber foliage in response to aphid and whitefly pressure. The application was made uniformly across all cucumber-containing treatments, using the same dose, timing, sprayer type and application procedure. Spraying was directed toward cucumber rows, while cowpea rows were not sprayed. Application was carried out under calm field conditions, with care taken to minimise spray drift to adjacent cowpea rows. Because all intercropping treatments received the same cucumber-targeted application, comparisons among T_3, T_4 and T_5 remain internally consistent.

Seasonal population dynamics of *Lampides boeticus*

From the onset of floral bud appearance on cowpea, five cowpea plants per plot were randomly selected from the central rows each week. Each plant was examined to record the number of *L. boeticus* eggs and larvae. Observations continued for ten consecutive weeks. Weekly mean values per plot were used to describe seasonal trends under each cropping system.

Damage assessment

During the pod-filling stage, 50 cowpea pods were sampled from the central rows of each plot and the number of infested and uninfested pods was documented. This was followed by the recording of the average number of holes per infested pod and the number of damaged seeds per infested pod. These data were then used to compute pod infestation (%), mean holes per pod and damaged seeds (%). To satisfy the normality assumption of ANOVA,

percentage data (pod infestation and damaged seeds) were transformed to arcsine-square-root values before ANOVA. Back-transformed means are presented in the tables.

Yield and land equivalent ratio

At physiological maturity, cowpea was harvested from the net cowpea area of each plot and grain yield was expressed on a per-hectare basis. Cucumber fruits were harvested at commercial maturity over multiple pickings and total fruit yield was expressed in t ha^{-1}. The land equivalent ratio (LER) was calculated according to Trenbath (1993) and Dimande *et al.* (2024) as:

$$LER = (Y_CP / Y_CS) + (Y_{JCJ}P / Y_{JCJ}S)$$

Where,

Y_CP and $Y_{JCJ}P$ = Intercrop yields of cowpea and cucumber, respectively.

Y_CS and $Y_{JCJ}S$ = Corresponding sole-crop reference yields.

An LER > 1 indicates that intercropping requires less land than sole cropping to achieve the same total production.

Weather dat

Weekly mean maximum and minimum temperatures and relative humidity during the cropping season were obtained from the nearest meteorological station and are summarized in Table 1.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) appropriate for an RCBD using the General Linear Model procedure (PROC GLM) of SAS (v. 9.4; SAS Institute Inc., Cary, NC, USA). Treatment means were compared using Duncan's multiple range test (DMRT) at $p \leq 0.05$. Pearson correlation coefficients were calculated between selected weekly weather variables and *L. boeticus* infestation parameters as an exploratory analysis; results should be interpreted with caution given the small sample size (n= 10 periods) and potential temporal autocorrelation.

RESULTS AND DISCUSSION

Seasonal population dynamics of *L. boeticus*

Larval counts of *L. boeticus* on cowpea increased progressively from the third week after sowing, peaked between Weeks 5 and 7 and declined as pod-filling advanced under all cropping systems. The maximum mean egg density was 3.5 eggs $plant^{-1}$ in sole cowpea at Week 6, while the maximum mean larval density was 3.4 larvae $plant^{-1}$ in sole cowpea at Week 6. The highest larval peak was recorded in sole cowpea (T_1), whereas peaks were markedly lower in all intercropped treatments, particularly in T_3 (1:1) and T_5 (1:2). A similar temporal pattern, associated with the peak availability of floral buds and tender pods, has been reported in previous studies from Iraq (Al-Karboli and Al-Janabi, 2017). The concurrent rise in maximum temperature and decline in relative humidity over the sampling period (Table 1) were consistent with conditions known to favour *L. boeticus* activity (Al-Karboli and Al-Janabi, 2017; CABI, 2023).

The lower larval peaks observed under intercropping are consistent with the host-dilution hypothesis, whereby the physical presence of cucumber plants reduces the effective cowpea density per unit area and impairs the host-finding ability of gravid female *L. boeticus*. This mechanism, together with canopy-mediated disruption of visual and olfactory host-location cues, has been widely invoked to explain pest suppression in legume-based intercropping systems (Trenbath 1993; Mushi *et al.,* 2020; Hassan, 2009; Masvaya *et al.,* 2017; Dingha *et al.,* 2021; Coulibaly *et al.,* 2024).

Severity of infestation and damage indices

Cropping system had a significant effect on all measured damage indices (ANOVA, $p<0.05$; Table 2). Sole cowpea (T_1) recorded the highest mean larval density (4.1 larvae $plant^{-1}$), pod infestation (48.0%), holes per pod (2.3) and proportion of damaged seeds (30.0%). Under the tested field-management conditions, all intercropping treatments

Table 1: Mean weekly maximum and minimum temperatures (°C) and relative humidity (%).

Week after sowing	Max. temp (°C)	Min. temp (°C)	Relative humidity (%)
1	27.5	14.2	58
2	28.9	15.0	56
3	30.3	16.1	54
4	31.8	17.4	52
5	33.2	18.6	49
6	34.7	19.8	47
7	35.9	21.0	45
8	36.5	22.1	43
9	37.0	23.0	41
10	37.5	23.5	40

Table 2: Effect of cropping systems on *L. boeticus* infestation indices on cowpea.

Cropping system	Mean larvae $plant^{-1}$	Pod infestation (%)	Holes per pod	Damaged seeds (%)
T_1: Sole cowpea	4.1a	48.0a	2.3a	30.0a
T_2: Sole cucumber	-	-	-	-
T_3: 1:1	2.7b	34.0b	1.7b	21.0b
T_4: 2:1	3.0b	37.0b	1.9b	23.0b
T_5: 1:2	2.4b	31.0b	1.6b	19.0b

significantly reduced these indices relative to T_1 (DMRT, $p \leq 0.05$), while no significant differences were detected among intercropping treatments (T_3, T_4, T_5). Mean larval density declined to 2.7, 3.0 and 2.4 larvae plant^{-1} in T_3, T_4 and T_5, respectively, while pod infestation fell to 34.0%, 37.0% and 31.0%.

The reductions in pod infestation and seed damage under intercropping (Table 2) indicate meaningful mitigation of economic losses attributable to *L. boeticus*. Comparable reductions in pest density and feeding damage have been reported in cowpea-based intercropping systems with cereals and other companion crops (Dingha *et al.* 2021; Coulibaly *et al.,* 2024). Among intercropping arrangements, T_5 (1:2) produced the lowest pod infestation and seed damage, suggesting that a higher proportion of cucumber in the canopy amplifies the host-dilution and host-finding disruption effects on *L. boeticus*. The absence of significant differences among T_3, T_4 and T_5 indicates that any cowpea-cucumber arrangement confers substantial pest suppression relative to sole cowpea.

Crop yields and land equivalent ratio

Sole cowpea (T_1) produced the highest grain yield (2,300 kg ha^{-1}), which declined significantly to 1,900, 2,100 and 1,750 kg ha^{-1} in T_3, T_4 and T_5, respectively (DMRT, $p \leq 0.05$; Table 3). Sole cucumber (T,) produced the highest fruit yield (25.0 t ha^{-1}), which was reduced to 18.0, 15.0 and 20.0 t ha^{-1} in T_3, T_4 and T_5, respectively. The lowest cucumber yield in T_4 (2:1) is attributable to the dominant proportion of cowpea rows, which reduced the cucumber area and intensified interspecific competition for resources. These yield reductions under intercropping are expected consequences of interspecific competition for light, water and nutrients (Mushi *et al.,* 2020; Hassan, 2009; Masvaya *et al.,* 2017).

Despite lower individual crop yields, all intercropping systems achieved total LER values of 1.51-1.56 (Fig 1), indicating that 51-56% more land under sole cropping would be required to achieve the same combined output. These LER values are consistent with those reported for comparable legume-based intercrops in semi-arid environments (Trenbath 1993; Dingha *et al.* 2021; Coulibaly *et al.,* 2024). From a management perspective, T_5 (1:2) achieved the greatest pest suppression and the highest LER (1.56) but the lowest cowpea grain yield (1,750 kg ha^{-1}), while T_3 (1:1) offered intermediate pest suppression, an LER of 1.55 and better cowpea yield retention (1,900 kg ha^{-1}). The preferred system depends on whether the farmer prioritizes pest suppression and overall system efficiency (T_5) or a more balanced retention of cowpea grain yield (T_3).

Relationship between weather factors and *L. boeticus* infestation

Pearson correlation analysis revealed a strong positive association between mean larval density and pod infestation ($r = 0.82$, $p \leq 0.01$; Table 4). Moderate positive

Table 3: Grain yield of cowpea, fruit yield of cucumber and partial and total land equivalent ratio (LER) under different cropping.

Cropping system	Cowpea yield (kg ha^{-1})	Cucumber yield (t ha^{-1})	LER_C	LER_{JCJ}	Total LER
T_1: Sole cowpea	2300a	-	1.00	-	1.00
T_2: Sole cucumber	-	25.0a	-	1.00	1.00
T_3: 1:1	1900b	18.0b	0.83	0.72	1.55
T_4: 2:1	2100b	15.0c	0.91	0.60	1.51
T_5: 1:2	1750b	20.0b	0.76	0.80	1.56

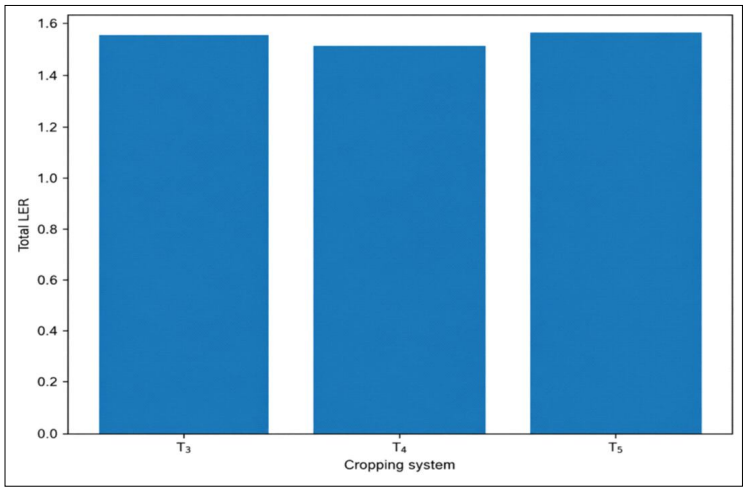


Fig 1: Total land equivalent ratio (LER) under intercropping systems (T_3, T_4, T_5).

Table 4: Pearson correlation coefficients (r) between selected weekly weather variables and *L. boeticus* infestation parameters on cowpea (n =10 weekly observation periods).

Variables compared	Pearson r
Mean larvae plant^{-1} × pod infestation (%)	0.82**
Mean larvae plant^{-1} × maximum temperature (°C)	0.69*
Mean larvae plant^{-1} × relative humidity (%)	-0.63*
Pod infestation (%) × maximum temperature (°C)	0.71*
Pod infestation (%) × relative humidity (%)	-0.66*

correlations were detected between maximum temperature and both larval density ($r = 0.69$, $p \leq 0.05$) and pod infestation ($r = 0.71$, $p \leq 0.05$). Relative humidity was negatively correlated with both larval density ($r = -0.63$, $p \leq 0.05$) and pod infestation ($r = -0.66$, $p \leq 0.05$). These associations should be interpreted as exploratory, given the small sample size (n = 10 weekly periods) and the potential for temporal autocorrelation to inflate correlation estimates. Nevertheless, the directional patterns are consistent with published ecological accounts of *L. boeticus* (Al-Karboli and Al-Janabi, 2017; Dingha *et al.,* 2021; Khidher, 2024) and confirm that warmer, drier conditions during flowering and pod-filling favour higher pest activity.

Methodological limitation related to pesticide use

A methodological limitation of the present study is the single cucumber-targeted deltamethrin application made at Week 6 in cucumber-containing treatments. Although the insecticide was not applied directly to cowpea rows and was used uniformly across all cucumber-containing treatments, deltamethrin is a pyrethroid insecticide that can affect insects through direct contact or ingestion (National Pesticide Information Center (NPIC) 2010). Therefore, a possible indirect effect through spray drift or altered arthropod activity cannot be completely excluded. For this reason, the reduction in *L. boeticus* infestation in intercropped plots should be interpreted as the combined outcome of the intercropping system under practical IPM field-management conditions, rather than as a purely pesticide-free intercropping effect. Future experiments should include an additional factorial treatment structure with sprayed and unsprayed intercropping plots, or completely exclude insecticides, to isolate the independent contribution of crop arrangement to *L. boeticus* suppression.

CONCLUSION

Under the tested practical IPM field-management conditions, cowpea-cucumber intercropping arrangements were associated with significantly lower *L. boeticus* larval density, pod infestation, holes per pod and damaged-seed proportion than sole cowpea ($p \leq 0.05$). Despite reductions in individual crop yields, all intercropping systems achieved total LER values of 1.51-1.56, demonstrating a consistent land-use advantage over sole cropping. The 1:1 (T_3) and 1:2 (T_5) intercropping arrangements provided the most favourable balance between *L. boeticus* suppression and land-use efficiency. The preferred system depends on whether the farmer prioritises pest suppression and overall productivity (T_5) or a more balanced retention of cowpea grain yield (T_3). Warmer temperatures and lower relative humidity during flowering and pod-filling were positively associated with *L. boeticus* activity and should be considered in the timing of intercropping-based IPM interventions.

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Disclaimers

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Informed consent

Not applicable. This study did not involve humans or experimental animals.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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