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The depth of *Cirina forda* Westwood (Lepidoptera: Saturniidae) Pupation in the soil as a determinant factor for its mortality rate

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Abstract
Prepupa larvae of *C. forda* metamorphosed into pupae in the soil. It is reported for marketing of the processed larvae of *C. forda* by the people of Benue State of Nigeria. Unfortunately the penultimate larvae of *C. forda* is facing crucial decline challenges in the contemporary times. A study to determine part of the factors responsible for the declining of *C.forda* was mounted by determining the depth of pupation in the soil as determinant factor for the mortality rates of pupae in the soil, and the contribution of the depth level towards successful emergence of imago after aestivation was carried out in Lavun and Rafi local government areas of Niger State within two cropping seasons. By carefully exhuming pupae within three random quadrat throws per site and then scraping the soil within the quadrat with a hoe or shovel to a depth of 30 cm. On each site a mean pupal density was calculated and expressed as individual's ± SD per m^2. Survival rates were subsequently determined as a proportion in percentage of the total number of pupae encountered per quadrat and per site and expressed as mean ± SD%. Results showed that the pre-pupae and pupae were found within 0-15cm depth across the sites with high mortality recorded within 0-8cm depth while pupal density declined with season. Causes of shallow pupation as a result of other soil factors are being investigated.

Keywords: depth, *Cirina forda*, pupation, mortality

Introduction
The pupal development of *Cirina forda* that is subterranean is initiated by a short lived pre-pupal stage. This pre pupal stage takes after the larval form but it is sturdier with a stout and well-fortified exoskeleton. Having shortened up, lost its capability for movement and feeding as well as its sharp coloration [1].

The pupae turn reddish-brown becoming harder and darker in coloration but remaining tranquil within its prepupal case around its abdomen in the pupal cell throughout the pupal stage lasting 266.3±2.6days [2].

The larvae and pre-pupae are widely used as an ingredient in vegetable soup [3]. Various harvesting techniques had been identified such as, picking from dug pits, picking from tree directly, picking from soil surface, picking from cut tree branches, and picking from digging inside soil [4].

The larvae and pre-pupae are particularly harvested from shea butter trees in July and August each year [5, 6]. Those who escaped harvest by either of the above harvesting techniques burry themselves into the soils at various depths [1]. There are various soil factors that determine their depth into the soils, mortality rates and emergence factors of the imago after dormancy season. This study determined the depth of pupation in the soil as determinant factor for the mortality rates of pupae in the soil, and the contribution of the depth level towards successful emergence of imago after aestivation.

Materials and methods
Study area
The study was carried out from Lavun and Rafi local govt. areas of Niger State, Nigeria, in 2016 and 2017 cropping seasons in Southern Guinea Savanna vegetation zone.

Sample Collection
Pupa samples: *C. forda* pupal population were determined once in the season on each site by carefully exhuming pupae within three random quadrat throws per site and then scraping the soil within the quadrat with a hoe or shovel to a depth of 30 cm. On each site a mean pupal density was calculated and expressed as individual's ± SD per m^2. The population of pupal occurrence at depth ranges of 0 - 15cm, and 16 - 30 cm were sorted out and noted while exhuming the pupae. The mean population of occurrence per range was determined per quadrat and per site and expressed as individual's ± SD per m^2.

The survival status of every pupa sorted out was determined as described by [7] and the number of survivors noted per quadrat per site. Survival rates were subsequently determined as a proportion in percentage of the total number of pupae encountered per quadrat and per site and expressed as mean ± SD%. The survival rate at 0 to 15 cm and 15 to 30 cm depths were also noted from the numbers of survivors encountered within the said range as described earlier.

Results
Table 1 showed where Lavun Local Government Area had pupae exhumed more in Tako Tswako site in 2017 and least in Shekpatanko Kutigi site in 2017. Like all sites in the local government area, the values were decreasing such that values recorded for all sites in 2017 were least except in Tako Tswako. All the pupae were recovered within the varying depth distribution range of 0 – 15 cm only. Not beyond.

Pupal mortality rate (%) in Lavun LGA was high in Effun Tiffin site in 2016 with the least depth of less than 8cm in the Local Government Area. However, Tako Tswako site recorded lowest rate of mortality in the local government area

as pupae were retrieved beyond 10cm depth but not up to 15cm.

Table 2, from Rafi LGA, Uragi site recorded highest value of pupae because within the site pupae were found beyond 10cm but less than 15cm depth in 2017. As Ushama site recorded the least in 2017. But all the pupae were retrieved within varying depth distribution range of 0 – 15cm.

Pupal mortality rate (%), Ushama site recorded highest mortality rate in the local government area with 100% mortality as all pupae discovered within the depth range of 4cm and 6cm followed by Shanuyanbu and Unguwar Faranshi sites.

Table 1: The abundance, depth and mortality rates of *C. forda* pupae in two cropping seasons at Lavun LGA, Niger State, Nigeria

Site	Pupal feature	*C. forda* Seasons of occurrence			
		2016		2017	
FRSC checkpoint	Number exhumed	77		76	
	Pupal density	14±5.19		14±3.96	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		3±1.21	---	1.9±1.7	---
	Pupa Mortality rate (%)	37.5		75.0	
Shekpatanko	Number exhumed	84		82	
	Pupal density	6±3.96		4±2.59	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		9±5.22	---	6±3.17	---
	Mortality rate (%)	21.0		72.9	
Effun Tifin	Number exhumed	72		70	
	Pupal density	2±1.5		1±1.5	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		5±3.96	---	5±3.96	---
	Mortality rate (%)	61.0		80.1	
Shekpatanko Kutigi	Number exhumed	72		64	
	Pupal density	7±3.00		7±2.59	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		1±0.0	---	7±3.0	---
	Mortality rate (%)	75.0		77.5	
Tako Tswako	Number exhumed	82		89	
	Pupal density	8±3.96		7±3.92	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		12±3.0	---	5±3.00	---
	Mortality rate (%)	24.44		41.1	
	Number exhumed	77		70	

Table 2: The abundance, depth and mortality rates of *C. forda* pupae in two cropping seasons at Rafi LGA, Niger State, Nigeria

Site	Pupal feature	*C. forda* Seasons			
		2016		2017	
Shanuyanbu	Number exhumed	48		40	
	Pupal density	2±1.59		2±1.19	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		7±2.5	---	6±5.1	---
	Mortality rate (%)	60.6		62.5	
Uragi	Number exhumed	43		48	
	Pupal density	5±1.5		4±1.5	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		5±1.5	---	4±1.5	---
	Mortality rate (%)	83.3		57.1	
Ushama	Number exhumed	41		30	
	Pupal density	4±1.00		3±0.00	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		4±1.00	---	3±0.00	---
	Mortality rate (%)	100		100	
Unguwar Faranshi	Number exhumed	41		40	
	Pupal density	5±0.00		4±0.00	
	Depth distribution	0-15cm	16-30cm	0-15cm	16-30cm
		5±0.00	---	4±0.00	---
	Mortality rate (%)	66.6		66.6	

Discussion

The pupation of *Cirina forda* took place around the base of host trees, *Vitellaria paradoxa*. This is in line with the findings of [7, 8, 2, 1]. However the depth of pupation in the soil varied with locations as was discovered in this trial compared with the study of [9] where final instars were recovered within the depth of 0-90cm depth and [8] posited that pupae preferred the depth of 20-30cm. However, generally shallow depth recovered high mortality rate in all sites this could be as a result of solar heat generated, and bush burning heat [8].

It is evident therefore that depth of pupation of *C. forda* larvae in the soil contributed immensely to the declining population of the insect on the wild.

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