similar work by a similar subject could be predicted to the first degree of approximation from

$$E\left(\frac{\text{Kcal}}{\text{min.}}\right) = 0\cdot074 \text{ W kg.}$$

Mahadeva *et al.* (1953) obtained a relation between gross weight and energy cost for walking on a horizontal plane ($E = 0\cdot047\ W + 1\cdot02$) and for step test ($E = 0\cdot066\ W$), with which the present equation bears comparison. The constant of multiplication in the present case is higher since stairclimbing is far more strenuous than walking.

The gross mechanical efficiency of physical work defined as,

$$100 \times \frac{\text{External work in kilogram meters} \times \text{Factor for conversion to Kcal.}}{\text{Internal energy expenditure in Kilocalories}}$$

$$= \frac{\text{Weight carried (kg.)} \times \text{Vertical height (m.)} \times 0\cdot234}{\text{E (Kcal./min.)} \times \text{Time of work (min.)}}$$

was computed in each case. The mechanical efficiency was found to have a mean value of 24·17% (range 20·0 to 28·6%). This gross mechanical efficiency of ascending stairs with loads upto 30 kg. may be taken as fairly constant. The efficiency values in the present study are quite compatible with such values reported for Occidentals for different muscular exercises (20–28%) (Bobbert, 1960) and for Indians climbing hills with a load 22·94% (Das and Saha, 1966).

Experimental studies on the same lines for establishing the relation between gross weight and energy cost and the constancy of mechanical efficiency under different conditions of work stress, rate and mode of carrying are in progress.

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HARMONIA ARCUATA FABRICIUS (COCCINELLIDAE)—PREDATORY ON THE RICE PLANT HOPPERS *SOGATELLA FURCIFERA* HORVATH AND *NILAPARVATA LUGENS* STÅL

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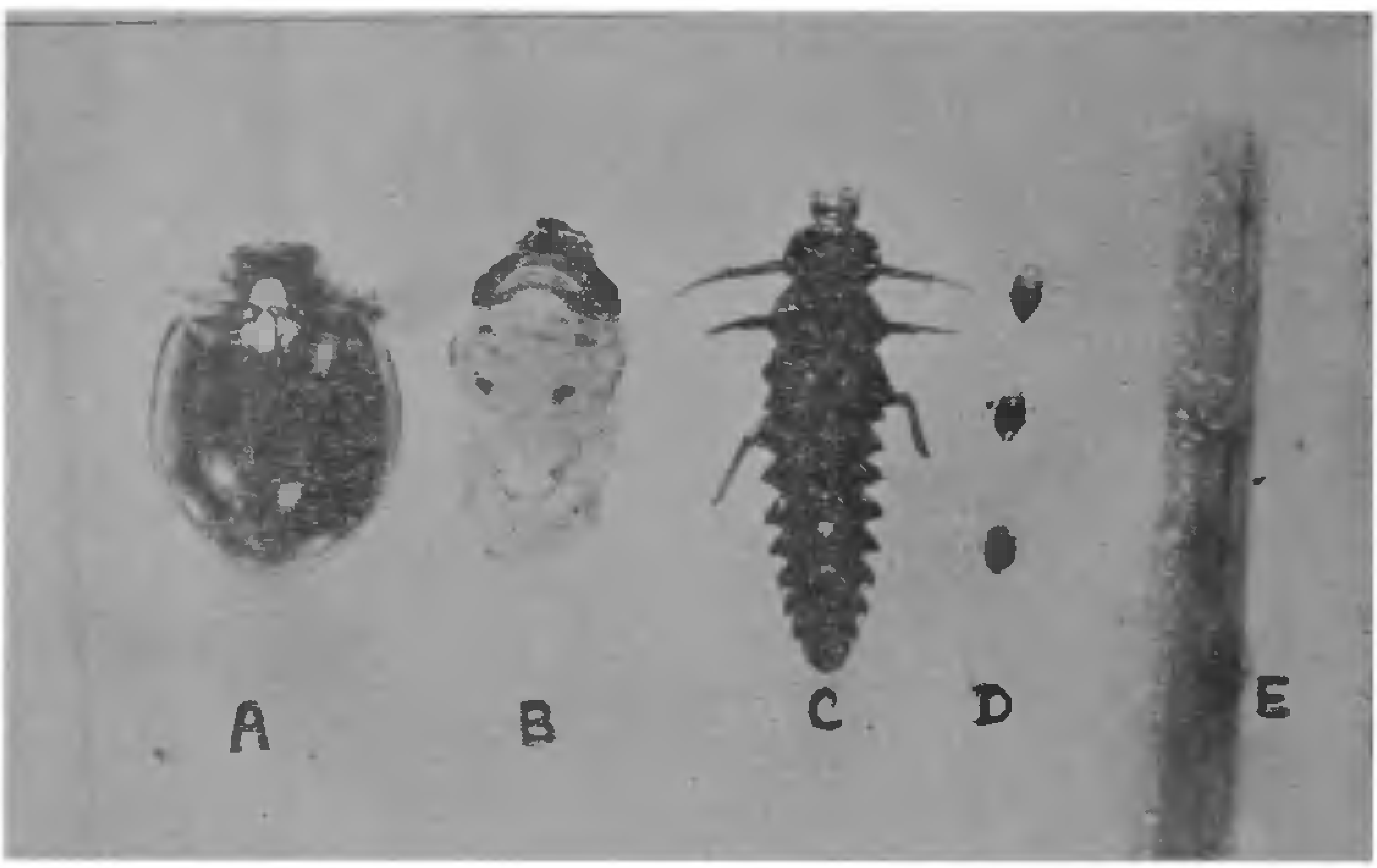
TWO species of delphacid plant hoppers, *viz.*, *Sogatella furcifera* Horvath, the white back plant hopper and *Nilaparvata lugens* Stål, the brown plant hopper have assumed major pest status in paddy with the intensive cultivation of high yielding rice varieties under high fertility levels. In addition to direct damage by sucking the sap and injecting toxins into the rice plant, their role as vectors of rice virus diseases has also been recognised recently in many parts of the world.

In the course of routine field observations on the parasites and predators of rice pests at the Central Rice Research Institute, Cuttack, during 1966 and 1967, the authors observed a coccinellid beetle as a predator on the two rice delphacids, *viz.*, *S. furcifera* and *N. lugens*. This has been identified as *Harmonia arcuata*

Fabricius and is the first record of its predacious habit on the two rice delphacids. "Normally this beetle has a number of black spots on its pronotum as well as the elytra. The elytral black spots tend to become confluent on the shoulder, in the middle and in the apical regions. In many cases, however, there is a reduction of spots both on the pronotum and the elytra. In the specimens (sent for identification) the reduction has gone to an extreme" (Kapur, 1967).

There was a severe incidence of white back plant hopper and the brown plant hopper in the standing *Kharif* (July-December) rice crops, particularly in the high yielding varieties during August and September in 1966 and 1967. Preliminary field observations during these two years indicated that the build-up of the plant hopper population in the rice fields was closely followed by a very rapid multiplication of this predacious beetle during mid-August to end of September. Besides, rice crops heavily infested with the above two hopper species invariably contained very large numbers of the beetle at all stages of development. The grubs and adults of this beetle appeared to check very effectively the hoppers' biotic potential by its predacious habit. The hopper population thus became gradually less by end of October after which the population of beetles also dwindled considerably. In view of its voracious feeding habit, it may prove to be an effective predator in the biological control of the rice plant hoppers.

Laboratory observations confirmed that the grubs as well as adults of this beetle readily fed on the nymphs as well as adults of *S. furcifera* and *N. lugens*, leaving behind portions of legs and wings. The eggs of *H. arcuata* were laid in clusters on rice leaves. The grub and pupal stages (Fig. 1) lasted for 16 to 20 and 4 to 5 days respectively and the adults lived for 10 to 12 days in the laboratory.



F . 1. *Harmonia ar.uata* Fabr (A) Adult ; (B) Empty pupal skin ; (C) Full-grown grub ; (D) Newly hatched grubs ; (E) Eggs on rice leaf.

Detailed studies on its life-history and its population dynamics in relation to rice plant hoppers are in progress.

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LETTERS TO THE EDITOR

ON THE EKMAN LAYER IN A ROTATING HYDROMAGNETIC FLUID

CONSIDER a situation, in which a large body of weakly conducting viscous incompressible, rotating fluid, initially at rest under gravity, is set into motion by the action of a steady uniform tangential stress applied at the horizontal free surface $z = 0$. Let H_0 be a uniform magnetic field imposed along Z-axis and Ω be the constant angular velocity about the same axis in a rotating frame of reference 0XYZ. Assuming that the induced magnetic field due to the flow may be neglected with respect to the applied magnetic field, it can be shown[1] that the velocity vector $\vec{v} = [u(z, t), v(z, t), 0]$ satisfies the equations of motion

$$\frac{\partial u}{\partial t} - 2\Omega v = \frac{\partial^2 u}{\partial z^2} - mu,$$
$$\frac{\partial v}{\partial t} + 2\Omega u = \frac{\partial^2 v}{\partial z^2} - mv, \qquad (1)$$

where

$$m = \frac{(\sigma\mu^2 H_0^2)}{\rho} \qquad (2)$$

The initial and boundary conditions are:

$$t = 0, \quad u = v = 0 \quad \text{for} \quad z \leqslant 0,$$
$$t > 0, \quad \frac{\partial u}{\partial z} = S, \frac{\partial v}{\partial z} = 0 \quad \text{at} \quad z = 0,$$
$$u \to 0, \quad v \to 0 \quad \text{as} \quad z \to -\infty. \qquad (3)$$

We solve this system of equations by the Laplace transform technique and obtain

$$u + iv = \frac{S\sqrt{\nu}}{2\sqrt{m + 2i\Omega}}\Big[e^{\sqrt{(m+2i\Omega/\nu)}\,z} \times erfc\left\{-\frac{z}{2\sqrt{\nu t}} - \sqrt{(m+2i\Omega)\,t}\right\} - e^{-\sqrt{(m+2i\Omega/\nu)}\,z}\, erfc\left\{-\frac{z}{2\sqrt{\nu t}} + \sqrt{(m+2i\Omega)\,t}\right\}\Big]. \qquad (4)$$

For small t, this expression leads to

$$u = S\left(1 + \frac{mz^2}{6\nu}\right)\left[2\left(\frac{\nu t}{\pi}\right)^{\frac{1}{2}} e^{-(z^2/4\nu t)} + z\left(1 + erf\,\frac{z}{2\sqrt{\nu t}}\right)\right]$$
$$v = \frac{1}{3}S\Omega\left[2e^{-(z^2/4\nu t)}\left(\frac{\nu t}{\pi}\right)^{\frac{1}{2}}\frac{z^2}{\nu} - \frac{z^3}{\nu}\left(1 + erf\,\frac{z}{2\sqrt{\nu t}}\right)\right], \qquad (5)$$

while for large t,

$$u = \frac{Se^{\alpha z}\cos(\beta z - \theta)}{r} - \left(\frac{\nu}{t\pi}\right)^{\frac{1}{2}}\frac{S}{m^2 + 4\Omega^2}\exp.\left(-\frac{z^2}{4\nu t} - mt\right) \times \{m\cos 2\Omega t - 2\Omega\sin 2\Omega t\},$$
$$v = \frac{Se^{\alpha z}\sin(\beta z - \theta)}{r} + \left(\frac{\nu}{t\pi}\right)^{\frac{1}{2}}\frac{S}{m^2 + 4\Omega^2}\exp.\left(-\frac{z^2}{4\nu t} - mt\right) \times \{2\Omega\cos 2\Omega t + m\sin 2\Omega t\}, \qquad (6)$$

where

$$\alpha, \beta = \sqrt{\frac{\Omega}{\nu}}\left(\sqrt{\lambda^2 + 1} \pm \lambda\right)^{\frac{1}{2}}, \quad \lambda = \frac{m}{2\Omega},$$
$$\tan\theta = \frac{\beta}{\alpha}, \quad r = (\alpha^2 + \beta^2)^{\frac{1}{2}}. \qquad (7)$$

For small t, the velocity changes appreciably over distances of order $(\nu t)^{\frac{1}{2}}$ and for large t, the first part of (7) represents the Ekman layers which are confined to a surface stratum whose depth is of order $1/\alpha$ from the free surface while the last terms represent the inertial oscillations very small in magnitude but persistent.

For $t \to \infty$ (in the steady case),[2] the fluid velocity has its maximum magnitude S/r and has a direction θ in a clockwise sense from the applied stress. With increase in the depth below the free surface, the direction of the velocity rotates uniformly in a clockwise sense and the magnitude falls off exponentially at what might be called the penetration depth equal to π/α, the direction is opposite to that at the surface. Figure 1 shows the projection of the velocity vector at a number of depths $8\sqrt{\Omega}z/\sqrt{\nu} = 0, -1, -2, \ldots$ (for $\lambda = 0$ and 1) on to a horizontal plane, the curve traced out by the end-points of the vector being a logarithmic spiral in each case. These are found to diminish in size with the increase in λ, *i.e.*, in the strength of the magnetic field.

The net flux of fluid volume in the surface layer across vertical planes is given by

$$Q_x = \frac{S\nu\lambda}{2\Omega(\lambda^2 + 1)}, \quad Q_y = -\frac{S\nu}{2\Omega(\lambda^2 + 1)} \qquad (8)$$

showing that the effect of the magnetic field is to contribute a flux (which vanishes