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Notes and Discussion

A Small, Inexpensive Microbalance Suitable for Field Use

ABSTRACT.—This paper describes the construction, calibration and operation of an electric balance that is designed for field use and suitable for objects whose weights are less than 60 mg.

Several companies manufacture balances sensitive enough to determine the mass of objects weighing less than 100 mg. However, in addition to being expensive, these instruments present several problems for biologists conducting field studies at remote locations: when packed for transit, they occupy a relatively large amount of space; they require a 110 or 220 volt power source or a heavy battery pack, and they must be set up on a stable, level surface and be adjusted before use. Because these balances are perceived as expensive, specialized items, taking them through customs of developing countries may result in inconvenience and/or high tariffs. This paper describes a small, rugged, inexpensive

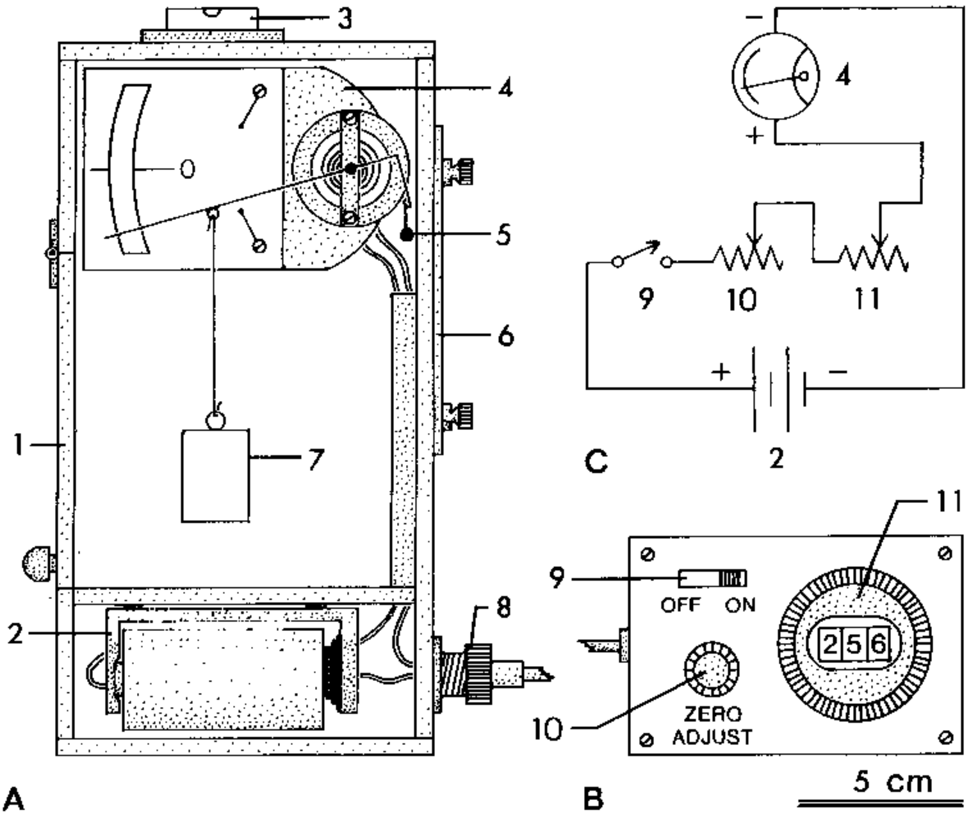

FIG. 1.—A. Balance. B. Control box. C. Wiring diagram. 1. hinged door to weighing chamber; 2. battery holder and 1.5 volt D cell; 3. bullseye level; 4. 1 milliamp meter with mirrored scale; 5. counterbalance weight; 6. access panel for counterbalance weight; 7. weighing pan (92 mg); 8. connector for wire to control box; 9. power switch; 10. zero adjustment potentiometer (3000 ohm, 5-turn, linear); 11. digital weighing potentiometer (100 ohm, 10 turn, linear, reading 0–1000)

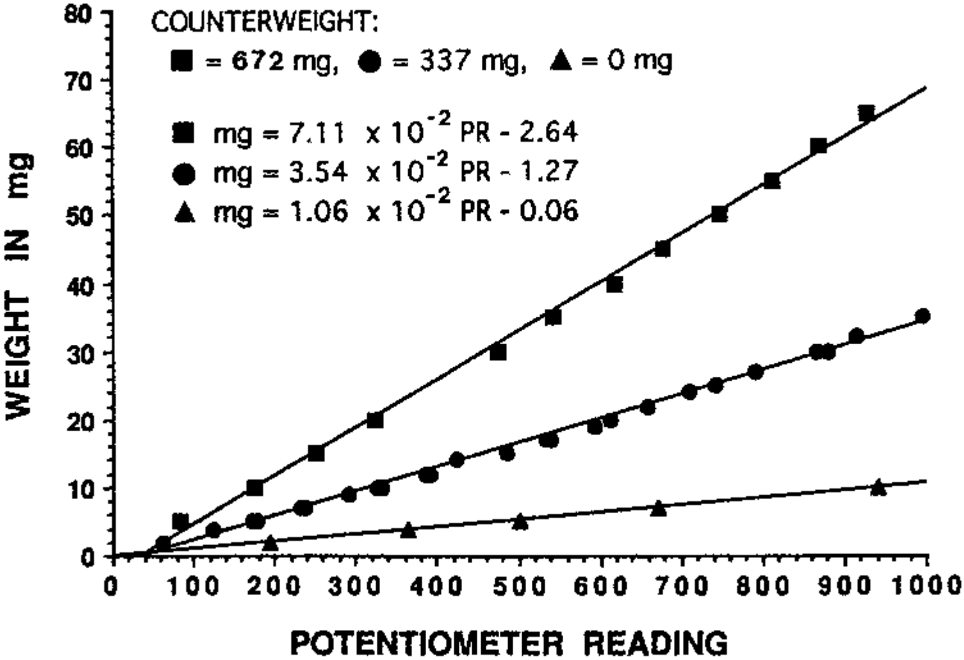

FIG. 2.—Calibration curves for the balance with different counterbalance weights in place

microbalance that operates on a 1.5 volt battery and can be constructed from materials that are readily available from electronic suppliers.

This balance consists of a battery holder, a power switch, two multiple-turn, linear potentiometers, and a modified analog electric milliamp meter that acts as a torque motor. These components are wired in series as shown in Figure 1. One potentiometer is used to zero the meter prior to weighing an object and the other to increase the current so that the needle returns to this zero point after an object has been placed on a weighing pan hanging from the meter's needle. The second potentiometer is connected to a digital (mechanical) readout that registers its rotation. By placing weights of known mass on the pan, a calibration curve (Fig. 2) is obtained, permitting the potentiometer readout to be converted to weight. Alternatively, a digital voltmeter could be connected in series between the second potentiometer and the meter and the current registered on this voltmeter, rather than potentiometer readings, used to construct a calibration curve.

The sensitivity and range of this balance depend on: (1) the size and sensitivity of the electric meter used; (2) the voltage supplied to the meter; (3) the point at which the weighing pan is attached to the meter's needle; (4) the adjustment of the meter's hair spring, and (5) the mass of a counterbalance weight hung from the end of the meter's needle opposite that of the weighing pan's attachment. A removable panel on one side of the balance permits this counterbalance weight and, thus, the range of the balance, to be easily changed (Fig. 1). However, the useful range of this balance is narrower than those of commercial balances (Fig. 2) and it must, therefore, be constructed for a specific use.

The specifications for a balance with a useful range of 0–60 mg are given in the legend of Figure 1. The hairspring of the balance's electric meter has been adjusted (using a screw located at the pivot point of the needle) so that it exerts no force on the needle: with the weighing pan and counterbalance removed and the meter in a horizontal position, the needle swings freely between its two stops as the meter is tilted slightly. If the force of the hairspring is not neutralized, both its tension and an object's weight will resist the needle's movement when current is supplied to the meter and the calibration lines shown in Figure 2 will be curved rather than straight.

For ease of operation, the balance and its control unit are housed in separate boxes, each constructed of clear plexiglas to facilitate airport security and customs inspections. A hinged side door provides access to the weighing chamber and eliminates air currents. A bullseye level atop the balance is sufficient to assure consistent performance when the balance is relocated. A threaded port can be added to the bottom panel of the balance, permitting the balance to be mounted on a tripod. A stirrup-shaped weighing pan can be made from the thin aluminum of a disposable weighing dish by bending a narrow strip of this material into a U and gluing its ends to a disk having a 2-cm diam.

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Reproductive Consequences of a Flower Color Polymorphism in Hydrophyllum appendiculatum

ABSTRACT.—This study examined the reproductive consequences of a discrete flower color polymorphism in a natural population of the woodland herb, *Hydrophyllum appendiculatum* (Hydrophyllaceae). Approximately 3% of the normally blue-flowered population consisted of completely white-flowered albinos. The two color morphs did not differ in flower size, seed weight, or in the number of seeds produced per inflorescence. However, average seed production per plant was much greater on blue-flowered plants. In contrast to other speciees with floral polymorphisms, the difference in seed production was not due to differential pollinator foraging behavior: the principal pollinator of *H. appendiculatum* (*Apis mellifera*) did not exhibit any preference for color morph. Rather, the difference in seed output was explained by the greater production of inflorescences by the blue morph. This finding suggests that the locus controlling flower color is genetically associated with the locus controlling inflorescence production.

INTRODUCTION

Flower color variation has been described in a wide range of animal-pollinated plants (Kay, 1978). This trait is of interest to evolutionary ecologists because of the central role that flower color plays in pollinator attraction and, ultimately, reproductive success (Waser, 1983). Variation in flower color within populations has been shown to have an impact on female and male reproductive success (Harding, 1970; Waser and Price, 1981), as well as outcrossing rates (Horovitz and Harding, 1972; Brown and Clegg, 1984; Schoen and Clegg, 1985; Epperson and Clegg, 1987). Differential success can arise when pollinators discriminate among flower color morphs resulting in one morph being undervisited (Waser and Price, 1983; Stanton, 1984). Individuals with more deeply colored flowers often receive greater pollinator service than do pale-colored or white (albino)-flowered genotypes (Waser and Price, 1981).

In addition to affecting fitness via pollinator behavior, loci controlling flower color may be associated with those coding for other traits which also impinge on the reproductive process. Sobrevila *et al.* (1989) reported that color morphs of tropical *Ipomoea imperati* differed in stigma-anther separation. In *Echium plantagineum* (Burdon *et al.*, 1983) and *Lupinus nanus* (Harding, 1970), albino individuals were poorer competitors and had lower relative fitness values than individuals with the wild-type flower color.

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