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Short Communication

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A Review of the McMorran Diet for Rearing Lepidoptera Species With Addition of a Further 39 Species

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Abstract

Research on cutworms led us to explore the use of the McMorran diet to rear lepidopteran species, mainly Noctuidae, under laboratory conditions. We documented the development of 103 lepidopteran species, including 39 species not previously reported in the literature, to be reared on this diet. Given its low cost, ease of preparation, and wide species' acceptance, this diet provides a powerful tool for facilitating Lepidoptera and other insects rearing and research in the laboratory.

Résumé

Une recherche sur les noctuelles nous a permis d'élever des larves de nombreuses espèces de lépidoptères, principalement des noctuelles, sur un substrat artificiel du nom de «McMorran diet» en laboratoire. Nous reportons le développement de 103 espèces de lépidoptères, dont 39 espèces qui n'ont pas encore été documentées, comme pouvant se développer sur ce substrat artificiel. Étant donné son faible coût, facilité de préparation, et large champ d'action, ce substrat artificiel peut grandement faciliter la recherche sur les lépidoptères et autres insectes en laboratoire.

Key words: artificial diet, caterpillar, Lepidoptera, Noctuidae, Tortricidae

Laboratory colonies of herbivorous insects are commonly reared on artificial diets to reduce the labor, time, space, and associated costs of growing their host plants. These diets also simplify the synchronization of insect development with the availability of food and can be optimized to increase insect fitness above that of insects reared on natural foods (McMorran 1965). Furthermore, the nutritional quality of these diets can be manipulated to facilitate research on topics including insect development, entomopathogens, insecticides, and plant resistance factors (George et al. 1960).

We used the McMorran diet to rear primarily pestiferous species of Noctuidae. This diet has been used as a suitable media to rear at least 153 species of insects, mainly Lepidoptera (Table 1). Adkisson et al. (1960) were the first to use wheat germ as an ingredient in an artificial diet they developed to rear the pink bollworm, *Pectinophora gossypiella* (Sauders) (Gelechiidae). This recipe was modified by Vanderzant et al. (1962) to rear the corn earworm, *Helicoverpa zea* (Boddie), and further modified by Berger (1963) to rear the corn earworm and the tobacco budworm, *Heliothis virescens* (F.) (Lepidoptera: Noctuidae). McMorran (1965) modified this later recipe to rear the spruce budworm, *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae). Grisdale (1973) subsequently added linseed oil as an ingredient to this latter recipe to reduce the incidence of wing deformities observed in other Lepidoptera species.

There are publications that provide artificial diet recipes with rearing methods of insects and their relatives and it is not our objective to review these articles. However, it is noteworthy to know the existence of notable publications that summarize diet recipes and rearing procedures, such as Smith (1966), Singh (1977), Singh and Moore (1985), and Wong (1972).

In this article, we provide a list of Lepidoptera that have been reared (i.e., larvae were able to develop) on the McMorran diet by previous researchers and by us. For each species, we provide comments indicating the suitability of the diet for rearing success (Table 1).

During 4 yr of research on Lepidoptera, we serendipitously discovered an increasing number of species that successfully develop on the McMorran diet but as it was not our objective to assess rearing success of insect species on this diet we do not have data on specific fitness of each species reared. Nonetheless, the information presented here should greatly ease rearing of Lepidoptera larvae and others for many studies. The research we conducted included rearing of field collected Lepidoptera larvae until either parasitoids emerged

Table 1. Species of Lepidoptera reared (i.e., were able to grow) on McMorran diet as reported in the literature and from this study

Species	Reference	Comments
Erebidae (Arctiidae)		
Estigmene acrea (Drury) [Saltmarsh caterpillar]	Barber et al. (1993) and this study	Reared from egg to at least third instar (Barber et al. 1993); Partly developed larvae reared to adults ($n = 3$) (this study)
Hyphantria cunea (Drury) [Fall webworm]	Morris (1967)	Reared over one generation and a partial second generation, severe wing deformities, degeneration
Lymantria monacha (L.)	Grijpma et al. (1987)	Reared for at least one full generation
Orgyia antiqua (L.) [Rusty tussock moth]	Grant (1977)	Likely at least one full generation
Orgyia cana Edwards	Grant (1977)	Likely at least one full generation
Orgyia definita Packard	Grant (1977)	Likely at least one full generation
Orgyia leucostigma (J.E. Smith) [Whitemarked tussock moth]	Percy et al. (1971), Grisdale (1973)	Reared over multiple generations
Orgyia pseudotsugata (McDunnough) [Douglas-fir tussock moth]	Nonmodified (Morris 1970, Grisdale 1973) and modified recipe (Lyon and Flake 1966)	Reared over multiple generations
Spilosoma congrua Walker	Barber et al. (1993)	Reared from egg to at least third instar
Spilosoma virginica (F.) [Yellow woollybear]	Barber et al. (1993), this study	Reared from egg to adult ($n = \sim200$)
Gelechiidae		
Filatima obscuroocelella (Chambers)	This study	Partly developed larvae reared to adults ($n = 7$)
Geometridae		
Lambdina fiscellaria fiscellaria (Guenée) [hemlock looper]	Otvos et al. (1973)	Reared for at least one full generation
Operophtera bruceata (Hulst) [Bruce spanworm]	Ives and Cunningham (1980)	Reared from egg to pupa
Operophtera brumata (L.) [Winter moth]	Feeny (1968)	Reared at least from eggs to pupae; modified recipe
Lasiocampidae		
Malacosoma disstria Hübner [Forest tent caterpillar]	Stairs (1965), Grisdale (1973)	Reared at least for one full generation
Noctuidae		
Abagrotis orbis (Grote)	This study	2^{nd} instars reared to adults ($n = \sim80$).
Abagrotis reedi Buckett	This study	Reared from egg to adult ($n = \sim50$)
Actebias balanitis (Grote)	This study	Reared from egg to adult ($n = \sim20$)
Actebia fennica (Tauscher)	?	Previously mentioned on the Insect Production Services website (when visited in 2012), but no longer is.
Agrotis ipsilon (Hufnagel) [Black cutworm]	Barber et al. (1993); this study	Reared for two generations ($n = \sim100$)
Agrotis vancouverensis (Grote)	This study	Reared from egg to adult ($n = \sim100$)
Anagrapha falcifera (Kirby) [Celery looper]	Barber et al. (1993); this study	Reared from egg to adult ($n = \sim80$)
Anaplectoides prasina (Denis & Shciffermüller)	This study	Reared from egg to adult ($n = \sim20$)
Anaplectoides pressus (Grote)	Barber et al. (1993)	Reared from egg to at least third instar
Anarta (Hadula) trifolii (Hufnagel) [Clover cutworm]	This study	Reared from egg to adult ($n = \sim100$); few specimens with deformed wings
Anticarsia gemmatalis (Hübner)	This study	Reared from egg to adult ($n = \sim70$)
Apamea devastator (Brace) [Glassy cutworm]	This study	Reared from egg to adult ($n = \sim2$)
Apamea lignicolora (Guenée)	This study	Reared from egg to adult ($n = \sim20$)
Apamea sordens (Hufnagel)	This study	Partly developed larvae reared to adults ($n = 5$)
Autographa bimaculata (Stephens)	This study	Last instar larvae reared to adults ($n = 2$)
Autographa californica (Speyer) [Alfalfa looper]	This study	Reared from egg to adult ($n = \sim200$)
Autographa flagellum (Walker)	Barber et al. (1993)	Reared from egg to at least third instar
Autographa precationis (Guenée)	Barber et al. (1993)	Reared from egg to at least third instar
Caradrina Morpheus (Hufnagel)	This study	Reared from egg to adult ($n = \sim100$)
Cerastsis salicarum (Walker)	Barber et al. (1993)	Reared from egg to at least third instar
Chrysodeixis includens (Walker)	Grisdale (1973); this study	Reared from egg to adult ($n = \sim60$)
Crocigrapha normani (Grote) [Climbing cherry cutworm]	Barber et al. (1993)	Reared from egg to at least third instar

(continued)

Table 1. Continued

Species	Reference	Comments
Cryptocala acadiensis (Bethune) [Catocaline dart]	Barber et al. (1993); this study	Reared from egg to adult ($n = \sim30$)
Cucullia intermedia Speyer [Goldenrod cutworm]	This study	Three last instars reared to adults ($n = 1$); the younger instars did not feed very willingly on the diet
Dargida diffusa (Walker) [Wheat head armyworm]	This study	Partly developed larvae reared to adults ($n = \sim20$)
Diachrysia aereoides (Grote)	This study	Partly developed larvae reared to adults ($n = 5$)
Diarsia rubifera (Grote)	Barber et al. (1993)	Reared from egg to at least third instar
Diarsia jucunda (Walker)	Barber et al. (1993)	Reared from egg to at least third instar
Eueretagrotis attenta (Grote)	Barber et al. (1993)	Reared from egg to at least third instar
Eupsilia tristigmata (Grote) [Brown fruitworm]	Barber et al. (1993)	Reared from egg to at least third instar
Eurois occulta (L.)	This study	Reared from egg to adult ($n = \sim60$)
Euxoa auxiliaris (Grote) [Army cutworm]	This study	Reared from egg to adult ($n = \sim50$)
Euxoa messoria (Harris) [Darksided cutworm]	This study	Reared for two generations ($n = \sim150$)
Euxoa ochrogaster (Guenée) [Redbacked cutworm]	This study	Reared for three generations ($n = \sim300$); ca. 5% adults had deformed wings
Euxoa satis (Harvey)	This study	Reared from egg to adult ($n =$ at least 1)
Euxoa tristicula (Morrison) [Early cutworm]	This study	Reared for five generations ($n = \sim600$)
Feltia herilis (Grote)	This study	Reared from egg to adult ($n = \sim30$)
Feltia jaculifera (Guenée) [Dingy cutworm]	This study	Reared for two generations ($n = \sim60$)
Helicoverpa zea (Boddie) [Corn earworm]	Grisdale (1973); this study	Reared for two generations ($n = \sim80$)
Heliothis virescens (F.) [Tobacco budworm]	This study	Reared for two generations ($n = \sim80$)
Homorthodes furfurata (Grtote)	Barber et al. (1993)	Reared from egg to at least third instar
Hyppa xylinoides (Guenée) [Cranberry cutworm]	Barber et al. (1993)	Reared from egg to at least third instar
Lacanobia grandis (Guenée)	Barber et al. (1993); this study	Reared from egg to adult ($n = \sim40$)
Lacanobia radix (Walker)	Barber et al. (1993)	Reared from egg to at least third instar
Lacinipolia renigera (Stephens) [Bristly cutworm]	This study	Reared from egg to adult ($n = \sim40$)
Lacinipolia sareta (Smith)	This study	Reared from egg to adult ($n = \sim50$)
Leucania multilinea Walker	Barber et al. (1993)	Reared from egg to at least third instar
Mamestra configurata Walker [Bertha armyworm]	Grisdale (1973); this study	Reared from egg to adult ($n = \sim50$); last instar was highly cannibalistic
Melanchra picta (Harris) [Zebra caterpillar]	This study	Partly developed larvae reared to last instar ($n = 3$); two of them died from parasitoids, the last one from disease.
Melanchra pulverulenta (Smith)	Barber et al. (1993)	Reared from egg to at least third instar
Morrisonia latex (Guenée)	Barber et al. (1993)	Reared from egg to at least third instar
Mythimna unipuncta (Haworth) [True armyworm]	Barber et al. (1993); this study	Reared for over five generations ($n = \sim1{,}000$)
Noctua pronuba (Linnaeus) [Large yellow underwing]	This study	Reared from egg to adult ($n = \sim20$); few specimens with deformed wings
Oligia illocata (Walker)	Barber et al. (1993)	Reared from egg to at least third instar
Orthosia revicta (Morrison) [Rusty whitesided caterpillar]	Barber et al. (1993)	Reared from egg to at least third instar
Peridroma saucia (Hübner) [Variegated cutworm]	Birch et al. (1976)	Reared for four generations
Phlogophora iris Guenée	Barber et al. (1993)	Reared from egg to at least third instar
Platyperigea multifera (Walker)	Barber et al. (1993)	Reared from egg to at least third instar
Plusia putnami Grote	This study	Last instars reared to adults ($n = 2$)
Pyrrhia exprimens (Walker)	Barber et al. (1993)	Reared from egg to at least third instar
Sideridis rosea (Harvey)	This study	Reared from egg to adult ($n = \sim20$); most adults with deformed wings
Spaelotis clandestina (Harris) [W-marked cutworm]	This study	Reared from egg to adult ($n = \sim20$)
Spodoptera eridania (Stoll)	This study	Reared for three generations ($n = \sim200$)

(continued)

Table 1. Continued

Species	Reference	Comments
Spodoptera exigua (Hübner) [Beet armyworm]	This study	Reared for two generations ($n = \sim 200$)
Spodoptera frugiperda (J.E. Smith) [Fall armyworm]	This study	Reared for two generations ($n = \sim 100$)
Trichoplusia ni (Hübner) [Cabbage looper]	Grisdale (1973); this study	Reared for at least three generations, multiple times ($n > 10,000$)
Trichordestra lilacina (Harvey)	This study	Reared from egg to adult ($n = 12$)
Xestia c-nigrum (L.)	Barber et al. (1993); this study	Reared from egg to adult ($n = \sim 40$)
Xestia smithii (Snellen)	Barber et al. (1993)	Reared from egg to at least third instar
Xylena nupera (Lintner)	This study	Partly developed larvae reared to adults ($n = 1$); wings of adult deformed
Zanclognatha pedipilalis (Guenée) [Grayish zanclognatha]	Barber et al. (1993)	Reared from egg to at least third instar
Pieridae		
Pieris napi (L.)	Barber et al. (1993)	Reared from egg to at least third instar
Pyralidae		
Dioryctria reniculelloides (Mutuura & Munroe) [Spruce coneworm]	Hamel (1977)	Field collected larvae to?
Dioryctria abietivorella (Grote) [Fir coneworm]	Trudel et al. (1995)	Fourth instars to adults
Ostrinia nubilalis (Hübner) [European corn borer]	Grisdale (1973)	Reared for at least one full generation
Saturnidae		
Hyalophora cecropia (L.) [Cecropia moth]	Grisdale (1973)	Reared for at least one full generation
Sphingidae		
Daphnis nerii (L.)	Retnakaran et al. (1985)	Reared over 30 generations
Hyles galii (Rottemburg) [Bedstraw hawk-moth]	This study	Penultimate instar to pupae ($n = 5$)
Manduca sexta (L.)	?	Previously mentioned on the Insect Production Services website (when visited in 2012), but no longer is.
Tortricidae		
Acleris gloverana (Walsingham)	Gray and Shephers (1993)	Field collected caterpillars reared until parasitoid emergence
Archips cerasivorana (Fitch) [Uglynest caterpillar]	Grisdale (1973)	Reared for at least one full generation
Choristoneura conflictana (Walker) [Large aspen tortrix]	Grisdale (1973)	Reared for at least one full generation
Choristoneura fumiferana (Clemens) [Spruce budworm]	McMorran (1965); Grisdale (1973)	Reared over multiple generations
Choristoneura occidentalis (Freeman) [Western spruce budworm]	Clancy (1991)	Reared over multiple generations; modified ingredients
Choristoneura pinus pinus (Freeman) [Jack pine budworm]	Allen et al. (1958)	Reared for multiple generations, degeneration observed
Choristoneura rosaceana (Harris) [Obliquebanded leafroller]	Barber et al. (1993)	Reared to at least third instar

from them or until they metamorphosed to adults for moths and parasitoids identification, and investigation of the host range of a parasitoid. The use of McMorran diet was ideal for these investigations. It allowed us to quickly handle high numbers of field collected caterpillars of various species. It saved us tremendous time, space, and money because we did not need to grow plants, and we did not need to develop species based rearing knowledge as we were pretty much ensured that any Noctuidae would develop on this diet. It also facilitated insects maintenance as the food remained good for at least 2 wk at 4°C and 5–7 d at room temperature (as per rearing conditions described under Materials and Methods section), and the rearing cages and cups remained relatively clean until insects completed their development.

Materials and Methods

To compile the list of Lepidoptera previously reported to have been reared on the McMorran diet, we examined all papers reported in the Web of Science, in Google, and Google scholar as citing "McMorran 1965" and "Grisdale 1973" (Table 1). Scopus was also searched but did not provide additional information.

For use in our laboratory, we purchased McMorran diet ingredients from the Insect Production Services (Great Lakes Forestry Centre, Canadian Forest Service, Sault Ste. Marie, ON, Canada). Ingredients were preserved for up to 6 mo in air-sealed packages (excluding linseed oil and potassium hydroxide (KOH), which were kept in bottles) at 2.5°C. We prepared new diet on a weekly basis in our laboratory; this diet was held for up to 2 wk at 4°C before use.

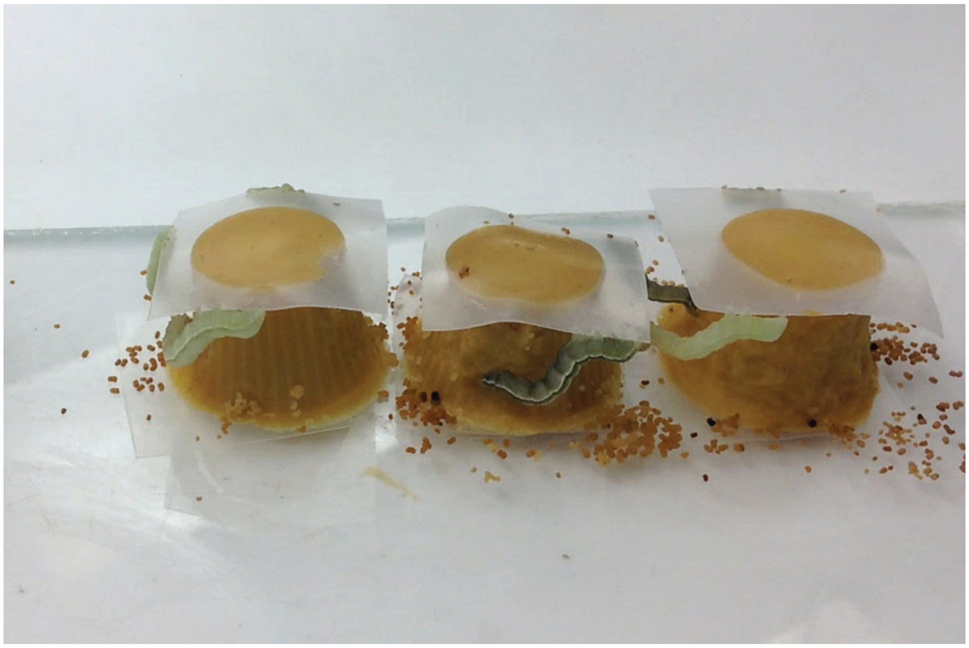

Fig. 1. Set up used to rear caterpillars in cages on the McMorran diet (in this picture: *Trichoplusia ni*).

Fig. 2. Set up for rearing cannibalistic species in cages. This picture shows a corner of a 60 by 47 by 44 cm Plexiglas cage used to rear 50 *Mamestra configurata* larvae (pupa visible in vermiculite). Three caterpillars died of disease, the others pupated but none were cannibalized.

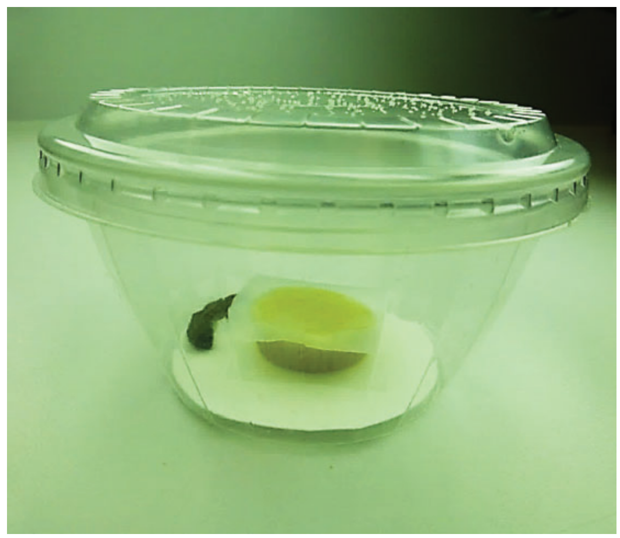

Fig. 3. Polar Plastic Ltd. cup (240 ml) used to rear individual caterpillars (in this picture: *Euxoa auxiliaris*).

The diet was prepared as per the recipe provided to us by Insect Production Services, which corresponds to that of Grisdale's (1973) modification of the recipe developed by McMorran (1965). Ingredients for 2-liter diet: 1,720 ml distilled water, 34.72 g agar, 70 g casein, 70 g sucrose, 61.39 g toasted wheat germ, 20 g Wesson's salt, 10 ml 4 M KOH, 10 ml linseed oil, 10 ml alphacel, 8 g ascorbic acid, 4.2 g aureomycin, 3 g methyl paraben, 2 g choline chloride, 1 ml 37% formalin, 20 ml vitamin solution. Ingredients for 2 l vitamin solution: 2 l water, 2 g nicotinic acid, 2 g calcium pantothenate, 2 g riboflavin, 0.5 g thiamine hydrochloride, 0.5 g pyridoxine hydrochloride, 0.5 g folic acid, 0.04 g biotin, and 0.004 g vitamin B12. To better preserve the vitamins, we replaced 200 ml (for 2 l of diet) of water by 200 g of crushed ice, which was blended with the hot mixture in a blender for one minute just before adding the vitamin solution in order to reduce temperature of the mixture. When the diet was ready, the head foam was scraped away, and the diet was poured into 22 ml plastic cups. When the diet was set ($\sim$30 min after pouring), these cups were refrigerated until use. Considering that we keep the ingredients already predivided for 2-liter batches, it takes us only 1 h to prepare one batch including washing of equipment.

Most lepidopteran species were purchased as eggs or recovered from adults collected from UV light traps. Commercial sources were Insect Production Services (Sault Ste. Marie, ON, Canada) and Benzon Research Inc. (Carlisle, PA). Importation of species from the United States was done with import permits issued by the Canadian Food Inspection Agency (Permit No. P-2011-04397, P-2013-02134, and P-2014-02394). Light traps were operated in the city of Lethbridge, Alberta, Canada, during the summer and fall of 2012–2014. Additional species were collected as larvae or eggs on various

Table 2. Lepidoptera species that do not successfully develop on McMorran diet in this study

Species	Comments
Drepanidae	
Habrosyne scripta (Gosse)	First instars ($n = \sim 60$)
Gelechiidae	
Syncopacma sp.	Partly developed larvae collected on *Lupinus argenteus* Pursh (Fabaceae) ($n = \sim 10$)
Hesperiidae	
Epargyreus clarus (Cramer) [silverspotted skipper]	Partly developed larvae ($n = 2$)
Nymphalidae	
Aglais milberti (Godart) [Milbert's tortoiseshell]	Partly developed larvae ($n = \sim 60$)
Coenonympha tullia (Müller)	First instars ($n = \sim 15$)
Limenitis arthemis (Drury) [White admiral]	Partly developed larvae ($n = 3$)
Papilionidae	
Papilio Canadensis (Rothschild & Jordan) [Canadian tiger swallowtail]	First instars ($n = 1$)
Papilio multicaudata Kirby	First instars ($n = 1$)
Pieridae	
Colias philodice Godart [Clouded sulphur]	Partly developed larvae ($n = \sim 20$)
Pieris rapae (L.)	Partly developed larvae ($n = \sim 50$)
Saturniidae	
Hemileuca eglanterina (Boisduval)	Partly developed larvae ($n = 2$)

plants in and near Lethbridge, and near Magrath (Cardston county), Alberta.

Eggs were recovered from field-collected adults by placing female moths in Plexiglass cages (40 cm by 34 cm by 30 cm [length × width × height]). A screened window (10 cm in diameter) on each side of the cage provided ventilation. The front of the cage had an opening (15 cm in diameter) with an attached cloth sleeve to provide access into the cage. Females were provided with sucrose crystals, water, and a choice of oviposition materials; i.e., cheese cloth, paraffin film ("Parafilm"), brown paper, paper towel, and fine sand. Eggs on the oviposition substrate were placed into new cages of the same design in which the hatched caterpillars were reared until pupation or until used in experiments. We usually reared about 50 caterpillars per cage (or 30 for Plusiinae). Eggs obtained commercially were similarly handled. For species maintained for more than one generation, pupae were placed in clean cages of this same design for emergence, mating, and oviposition.

In the laboratory, insects were reared in growth cabinets at 20°C, 70–80% humidity, and 12:12 (L:D) h cycle under low incandescent and fluorescent lighting. Caterpillars were provided with blocks of diet (20 cm^3) positioned mainly near the sides and corners of the cage. Small pieces of paraffin film (~9 cm^2) placed beneath and on top of each diet block facilitated its removal, reduced desiccation, and allowed caterpillars to feed while standing on the underside of the upper piece of the paraffin film (Fig. 1) as they would under a plant leaf in natural conditions. Fresh diet was added about every 5–7 d when the previous one became too old or dry. The diet had to be replaced about four times to sustain complete larval development of most species reared. For cages with first- to third-instar larvae, and any instar of Plusiinae (i.e., "loopers"), fresh diet blocks were placed as close as possible to the old blocks to facilitate the movement of caterpillars onto the fresh diet as these caterpillars have difficulty moving on the floor of the cage. Blocks of old diet were removed from cages after about 10 d.

Variously sized pieces of brown paper (laid flat or slightly crumpled) were placed in the cages of Noctuidae species (except Plusiinae) to provide sheltered areas. This noticeably reduced diurnal activity of the caterpillars and biting of each other (V.A.D.H., personal observation). Cannibalism of aggressive species (e.g., bertha armyworm and corn earworm) was further reduced by placing an increasing amount of crumpled brown paper, using bigger cages, having fewer caterpillars in a cage, and adding of a few centimeters of vermiculite on the bottom of the cage (Fig. 2).

Lepidoptera larvae were also reared individually in translucent plastic (Polar Plastic Ltd.) 8 oz (240 ml) containers (Fig. 3). These included caterpillars hatched from eggs in the laboratory or collected outside (same species as these reared in cages). A nonthreaded sewing machine was used to ease piercing of holes (0.5 mm in diameter) in the bottom and lid of containers to prevent the accumulation of condensation within. This reduced the incidence of mold on the diet and prevented early-instar larvae from becoming trapped and dying in water droplets. Each cup contained a piece of filter paper (55 mm in diameter) onto which a block of diet was placed (6.7 or 10 cm^3, depending upon the size of the larva), with a piece of paraffin film beneath and on top as described previously. Rearing conditions were as described for caterpillars reared in cages. The caterpillars pupated either in their cages or individual cups. They remained this way under the conditions described above until moth emergence.

Results and Discussion

The results of our literature search and laboratory studies are reported in Tables 1 and 2. Many studies do not report if the diet used contained linseed oil as per Grisdale's modification (1973) or any other modification. Table 1 reports Lepidoptera species successfully reared on the McMorran diet, whereas Table 2 reports species that we were unable to rear on this diet. Grisdale (1973) reports successfully rearing grasshoppers, *Melanoplus* spp. (Orthoptera: Acrididae) on the McMorran diet for at least one generation.

Rearing successive generations of Lepidoptera on nutritionally unbalanced diets can cause wing deformities (Morris 1967; V.A.D.H. personal observation), reductions in insect weight, fecundity, longevity, and increased mortality of all life stages (Morris 1967). The suitability of the McMorran diet for rearing successive generations of the species listed in Table 1 typically was not assessed. Some species were unwilling or unable to feed on McMorran diet as early instars but fed on the diet in later instars to complete their development; i.e., *Hyles* *euphorbiae* (L.) (Sphingidae) ($n = \sim 17$; most adults had deformed wings) and *Polychrysia esmeralda* (Oberthür) (Noctuidae) ($n = \sim 60$; no deformed wings observed). These are indications that further modification of the McMorran diet is needed to maintain laboratory colonies of these species.

Minor modifications to the McMorran diet can enhance rearing success. For example, Syme and Green (1972) reared larvae of European pine shoot moth, *Rhyacionia buoliana* (Denis & Schiffermüller) (Tortricidae) with the addition of 1 ml soya bean oil per 100 ml of McMorran diet. Gardiner (1970) reared to adults larvae of 49 identified species (and additional unidentified species) of Cerambycidae (Coleoptera), 17 of them from the egg, by adding 5 ml of dried pulverized host plant material to 100 ml McMorran diet. Similarly, Trudel (1994) successfully reared immature stages of the white pine weevil, *Pissodes strobi* Peck (Coleoptera: Curculionidae), and maintained adults, by adding 5% pulverized white pine bark to the McMorran diet.

Other diets similar in composition to the McMorran diet include that of Adkisson et al. (1960), Vanderzant et al. (1962), and the "Vanderzant-Adkisson special wheat germ diet" (marketed by MP Biomedicals, headquartered in Santa Ana, CA), which have also been used to rear a wide range of Lepidoptera and some Coleoptera species. This ability has been attributed to their wheat germ base (Cohen 2004).

Research that requires maintenance of laboratory colonies over multiple generations or aiming to study species performance should try to determine suitability of the McMorran diet for specific species, which may require adjustments of the recipe and further investigation into insect performance, to ensure maintenance of healthy colonies. Nonetheless, we showed that the McMorran diet can be used to facilitate the laboratory rearing of numerous species, both in cages and in 240 ml containers, and can likely be used to rear many more species than those reported here.

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