MATURATIONAL AND VARIETAL INFLUENCES ON SUNFLOWER CONSUMPTION BY RED-WINGED BLACKBIRDS

J. RUSSELL MASON, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Denver Wildlife Research Center, % Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104-3308
RICHARD A. DOLBEER, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Denver Wildlife Research Center, Ohio Research Station, % Plum Brook Station, 6100 Columbus Avenue, Sandusky, OH 44870
PAUL P. WORONECKI, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Denver Wildlife Research Center, Ohio Research Station, % Plum Brook Station, 6100 Columbus Avenue, Sandusky, OH 44870
ROGER W. BULLARD, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Denver Wildlife Research Center, Building 16, Denver Federal Center, Denver, CO 80225-0266

Abstract: Damage to oilseed sunflower by red-winged blackbirds (*Agelaius phoeniceus*) can be severe. One promising means to reduce this damage is to develop bird resistant varieties of sunflower. We report field, outdoor aviary, and laboratory assessments of red-winged blackbird preference for 2 sunflower varieties: Jacques Discovery (JD, a commercial oilseed cultivar), and Neagra de Cluj (NdC, an experimental bird resistant cultivar) at 6 dates during the course of seed development. Field results showed that red-winged blackbirds preferred JD to NdC, although NdC was eaten when JD became unavailable. Aviary and laboratory findings were consistent with these data. Observed preferences for JD may reflect the relatively high oil content of this variety. Conversely, low consumption of NdC may result from high levels of anthocyanins present in the seed hulls. Varietal resistance may represent a viable approach for the control of bird depredations in sunflowers. However, the influence of oil and anthocyanin levels and morphological characteristics require further clarification.

J. WILDL. MANAGE. 53(3):841–846

Damage by red-winged blackbirds and other avian species (e.g., house sparrows [*Passer domesticus*]) to oilseed sunflower in North Dakota, South Dakota, and Minnesota can be severe (Besser 1978). This damage can occur at any time from early seed development (about 5 days after bloom) to harvest (Cummings et al. 1987). Development of bird-resistant varieties of sunflower could be an ideal solution to the problem. Morphological features thought to increase resistance include concave heads, long bracts, heads that face the ground, head-to-stem distance >15 cm, and seeds with tough fibrous hulls held tightly in the head (Parfitt 1984). Chemical features thought to increase resistance include the anthocyanins (i.e., purple pigments) in the seed hulls of some varieties (Dolbeer et al. 1986, Mason et al. 1986). Anthocyanins may decrease the palatability of achenes by imparting astringency and/or bitterness (J. R. Mason, unpubl. data). The objective of our experiments was to evaluate developmental changes in the relative acceptability of NdC, a purple variety with high anthocyanin levels in the seed hulls, and JD, a commercial oilseed cultivar.

We thank G. E. Bernhardt, K. E. Brugger, and S. L. Lewis for technical assistance. L. Clark, J. L. Cummings, R. M. Engeman, K. A. Fagerstone, J. F. Heisterberg, G. M. Linz, D. L. Otis, and R. D. Thompson provided valuable comments on earlier manuscript drafts.

METHODS

We conducted 2 field tests: 1 in Ottawa National Wildlife Refuge, Lucas County, Ohio, and the other in Erie County, Ohio (exp. 1). At Ottawa, NdC and JD were planted on 4 June 1986 in a randomized complete block design. The cultivars were planted in 4 replicate blocks, each containing 2 plots and 12 rows (9 × 90 m). The 2 cultivars were randomly assigned to plots in each block. Blocks were 55 m apart and were located 1.5 km south of Metzger Marsh, a traditional late summer roosting site for blackbirds next to Lake Erie. One block was eliminated from the study because standing water caused poor growth of sunflowers.

Each plot was visited at 2-day intervals from 28 July to 11 August in which 100 heads were examined to establish the date when 50% of the heads had bloomed (i.e., ≥1 ray flower unfolded). Each plot was also assessed for bird damage (Dolbeer 1975) at 5, 10, 15, 25, 35, and 45 days after 50% bloom (DAB). These assessments involved visually estimating percent loss and measuring the total head diameter and undeveloped head center (Dolbeer 1975) for 5 heads in each of 12 randomly selected subplots.

Table 1. Mean bird damage (cm^2 seed loss/head/day) to 3 plots of Neagra de Cluj (NdC) and Jacques Discovery (JD) sunflowers at Ottawa National Wildlife Refuge, Ohio, 1986.

	Days after bloom						
Variety	1–5	6–10	11–15	16–25	26–35	36–45	1–45
NdC	0	0.1	0.8	6.1	11.8	2.1	4.5[a]
JD	0	0.2	2.7	11.1	8.2	3.3	5.3[a]
$\bar{x}$	0A[b]	0.2A	1.7A	8.6B	10.0B	2.7A	

[a] Mean damage/head/day was not significantly ($P > 0.10$) different for NdC and JD.
[b] Means with different letters were significantly ($P < 0.05$) different, Tukey's HSD tests.

For each maturity date, the new damage (amount of damage since last assessment) was divided by the number of days since the last assessment to obtain an estimate of the amount of damage/day. Damage data were analyzed in a 3-way between and within analysis of variance (ANOVA) in which the between factors were field blocks and treatments (varieties), and the within factor was DAB. We used Tukey's Honestly Significant Difference (HSD) procedure (Winer 1962) to isolate significant differences among means ($P < 0.05$).

The population size of the roost was estimated on 12 August and 3 and 24 September. Two or 3 observers estimated numbers entering the roosts in the evening by block-counting flightlines of birds (Meanley 1965).

The field test in Erie County involved planting NdC and JD on 14 June 1986 in 2 adjacent 24 row plots (18 × 180 m). From 6 to 16 August, a section of each plot was visited at 2-day intervals and the stems of heads with newly opened ray flowers were marked with spray paint. A different color was used each day to establish marked populations of plants of synchronous maturity for use in the aviary and laboratory tests described below. Bird damage to each plot was assessed on 6 dates from 17 September to 22 December by examining 5 heads in each of 16 randomly selected subplots.

Aviary tests were conducted in Erie County, Ohio (exp. 2). Thirty-six adult male red-winged blackbirds were caught in mist nets in July and housed in 6 2.4- × 2.4- × 1.8-m outdoor cages (6 birds/cage).

On 6 dates from 19 August to 29 September (i.e., 5, 10, 15, 25, 35, and 45 DAB), 46 NdC and 22 JD heads of synchronous maturity were collected from the field at 0800 hours by cutting the stalks 15 cm below the head. Fresh heads were placed in 8 vertical 50-cm lengths of plastic pipe (3.8 cm diam), attached at 23-cm intervals to wooden racks. The racks were then positioned along the center of the floors of the cages. In each of 3 cages, 4 heads each of NdC and JD were randomly assigned to a position on the rack. Adjacent heads faced opposite directions, and birds could not reach 1 head by perching on another. In each of the remaining 3 cages, 8 NdC heads were placed on racks in a no-choice evaluation. For all 6 cages, food was removed at 0800 hours and the racks were placed in the cages for 6 hours (0900–1500 hr). Five of the remaining heads of each variety were frozen in liquid nitrogen by 0830 hours and stored in a freezer and the other 5 heads were air-dried. Subsequently, air-dried and frozen heads were used in other studies.

Aviary test data were assessed in a 3-factor ANOVA (cages, treatments [varieties], DAB), with repeated measures within cages, and over maturity dates. Data comparing seed consumption for the no-choice test and the 1-choice test were assessed in a 2-factor ANOVA (test regime, maturities), with repeated measures within cages, and over maturity dates. We used Tukey's HSD tests to isolate significant differences among means ($P < 0.05$).

The laboratory assessment was conducted at the Monell Chemical Senses Center (exp. 3). Seeds were removed from the heads and stored in an ultra deep-freeze (−40 C). The samples remained in the freezer until 30 minutes prior to behavioral tests.

Twenty-four adult male red-winged blackbirds were randomly selected from the laboratory colony. The birds were individually housed in 61- × 36- × 41-cm cages under a 6:18-hour light:dark cycle (Mason and Reidinger 1982). Water was always available, and the birds were permitted free access to Purina Flight Bird Conditioner (PFBC) (Purina Mills, St. Louis, Mo.) and crushed shell grit.

For 5 days prior to the experiment, the birds were adapted to a deprivation regime that involved removing all food from the cages just

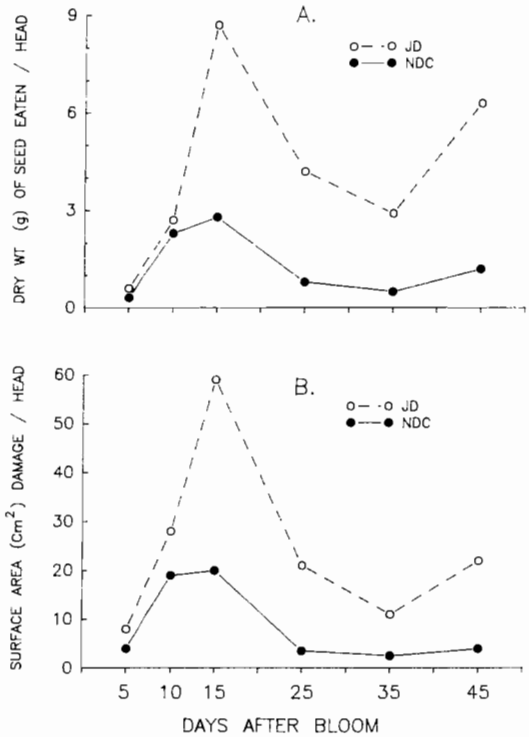

Fig. 1. Mean percent bird damage to 3 plots each of Neagra de Cluj (NdC) and Jacques Discovery (JD) sunflowers in relation to calendar date (A) and stage of maturity (B), Lucas County, Ohio, 1986. Each plot was assessed for damage at 5, 10, 15, 25, 35, and 45 days after 50% bloom.

before dark. Within 30 minutes after light onset on each of the next 5 days, the birds were presented with 2 cups (7.5-cm diam), each containing 20 g of PFBC. After 2 hours, the cups were removed from the cages, and the amount of PFBC remaining (defined as consumption) was assessed. Hoppers containing PFBC were then replaced in the cages for 4 hours until dark, when food again was removed. At the end of day 5, birds were assigned to 6 groups of 4 birds/group, on the basis of consumption during the adaptation period. Specifically, the bird with the highest consumption was assigned to the first group, that with the second highest to the second group, and so forth. The next 6 birds were assigned to groups in the opposite order. This method of assignment assured that all groups were balanced with respect to consumption prior to treatment. A priori, we assumed that consumption of PFBC reflected eating behavior in general, and that the groups would be approximately equal with respect to consumption of other foods including sunflower achenes.

Table 2. Estimated bird[a] damage to Neagra de Cluj (NdC) and Jacques Discovery (JD) sunflowers in adjacent 0.3-ha plots, Erie County, Ohio, 1986. The sunflowers bloomed during the first 2 weeks of August.

	NdC		JD	
Date	% seeds consumed	% heads damaged	% seeds consumed	% heads damaged
17 Sep	0.4	1	28.5	53
22 Oct	0.3	6	44.2	76
31 Oct	0.2	9	43.6	90
17 Nov	0.8	25[b]	44.9	93
25 Nov	1.5	19[b]	44.3	93
22 Dec	2.1	48[b]	60.6	98

[a] Mainly goldfinches and house finches.
[b] Loss may have been due to wind and rubbing.

Beginning on day 6, and for 6 consecutive days thereafter, all groups were given 1-choice tests between 5-g samples of NdC and JD seeds. Testing occurred during the 2 hours following light onset. Over the course of testing, each bird was presented once with samples of each variety at each maturity (e.g., 5 DAB NdC vs. 5 DAB JD). Different groups were given different orders of maturity according to a Latin square design (individuals within groups received the same order).

Laboratory results were assessed in a 3-factor ANOVA (groups, DAB, varieties) with repeated measures within varieties, and over maturities. We used Tukey's HSD tests (Winer 1962) to isolate significant differences among means ($P < 0.01$).

RESULTS

Experiment 1

Field Test (Lucas County).—For JD, 50% of the heads were in bloom on 2 August, 6 days before 50% bloom for NdC. Overall, there were no significant ($F = 7.4$; 1, 2 df; $P > 0.10$) differences in damage between the 2 varieties during the 45-day assessment period; NdC averaged 4.5-cm² loss/head/day versus 5.3-cm² loss for JD (Table 1). There were differences in damage among DAB ($F = 179.9$; 5, 10 df; $P < 0.00001$), and maximum damage occurred from 16 to 35 DAB. Neagra de Cluj received the most damage from 26 to 35 DAB and JD received the highest damage between 16 and 25 DAB.

The plots were subject to heavy bird depredation, and both varieties had >90% of the seed removed by 45 DAB (Fig. 1). A high level of damage (i.e., >30%) did not occur to NdC, however, until JD had received >80% loss.

Estimated numbers of birds at the roost were

Table 3. Mean sunflower seed consumption by red-winged blackbirds in 1-choice (Neagra de Cluj [NdC] vs. Jacques Discovery [JD]) and no-choice (NdC only) aviary tests at 6 maturities, 1986.

Measure of seed consumption	Variety/test[a]	Days after bloom						
		5	10	15	25	35	45	$\bar{x}$
Surface area (cm^2), loss/head	NdC/FC	4.0	19.5	20.4	3.5	1.4	4.1	8.8[b]
	JD/FC	8.1	28.5	58.6	20.4	10.0	22.0	24.6[b]
	$\bar{x}$/FC	6.0A[c]	24.0B	39.5C	12.0A	5.7A	13.1A	16.7[d]
	NdC/NC	6.6A[c]	23.9B	32.6B	12.9A	7.4A	7.6A	15.1[d]
Biomass consumed, g/head	NdC/FC	0.32	2.39	2.78	0.81	0.40	1.06	1.29[b]
	JD/FC	0.52	2.71	8.56	4.07	2.85	6.24	4.15[b]
	$\bar{x}$/FC	0.42A[c]	2.55B	5.66C	2.43B	1.62AB	3.65B	2.72[d]
	NdC/NC	0.47A[c]	2.16B	4.49C	3.17B	1.86AB	2.15B	2.38[d]

[a] FC = 1-choice, NC = no-choice.
[b] Mean consumption/head for the 2 varieties in the 1-choice test were significantly ($P < 0.01$) different, ANOVA.
[c] Means for the 6 maturing dates with different letters are significantly ($P < 0.05$) different. Tukey's HSD tests.
[d] Mean consumption/head in the 1-choice (NdC vs. JD) and no-choice tests (NdC only) were not significantly ($P > 0.10$) different, ANOVA.

41,000, 31,800, and 41,800 on 12 August, and 3 and 24 September, respectively. Species composition was about 70% red-winged blackbirds with the remainder being starlings (*Sturnus vulgaris*) and brown-headed cowbirds (*Molothrus ater*). Daily flightlines to and from the roost passed directly over the sunflower plots.

Field Test (Erie County).—Although no statistical inferences could be made in this unreplicated evaluation, the birds showed a clear preference for the JD plot over the NdC plot (Table 2). The former had 28% of the seed removed by 17 September (approx 35 DAB) and this loss increased steadily to 60% by 22 December; by contrast, NdC had experienced only 2% loss by 22 December.

Bird numbers and species composition in the Erie County plots were different from those in the Lucas County plots. A flock of 50 to 100 goldfinches (*Carduelis tristis*) and house finches (*Carpodacus mexicanus*) was usually observed in or near the plots during damage assessments. However, only a few small (<25 birds) flocks of red-winged blackbirds were observed in the field.

Experiment 2

Aviary Tests (Erie County).—In the 1-choice test, JD sustained significantly ($F = 76.7, 50.5$; 1, 2 df; $P < 0.01$) more loss/head than did NdC. There were also significant differences in cm^2 and biomass loss among the 6 maturity dates ($F = 11.7, 6.6$; 5, 10 df; $P < 0.01$), with the highest losses occurring at 15 DAB (Table 3). However, the pattern of loss in relation to maturity differed somewhat for the 2 varieties (i.e., the 2-way interaction between varieties and maturity dates was significant [$F = 7.4, 6.8$; 5, 10 df; $P < 0.01$]) for cm^2 and biomass loss. Loss was similar for NdC and JD at 5 and 10 DAB, but JD received significantly more loss than NdC at 15 DAB and the later maturities.

Differences in damage among maturity dates for each variety were more pronounced for surface area loss than for dry weight biomass consumed (Table 3). For example, nearly 6 times more seed of JD was removed/head at 15 than at 35 DAB, but this represented only a 3× difference in biomass consumed. Thus, birds had to consume more seeds at 15 compared to 35 DAB to obtain equivalent biomass.

In the no-choice test for NdC, there were significant differences among DAB ($F = 15.5$; 5, 20 df; $P < 0.00001$) in mean areas of damage (cm^2). Damage at 15 DAB was relatively greater than damage on any of the other 5 dates. However, there were no differences among DAB in mean biomass consumed ($F = 2.6$; 5, 10 df; $P = 0.094$).

In the no-choice test for NdC, the mean seed consumption/head was not significantly ($F = 0.9, 0.7$; 1, 4, df; $P > 0.10$) different from that measured for NdC and JD combined in the 1-choice test (Table 3). Thus, the markedly reduced consumption of NdC seeds established in the 1-choice test was not maintained when only NdC was available. The pattern of seed loss among maturity dates for NdC was similar in the no-choice and 1-choice tests; the highest consumption occurred at 15 DAB in both tests.

Experiment 3

Laboratory Assessment (Monell).—There were no differences among groups of birds (F

= 1.3; 5, 18 df; $P = 0.32$); however, consumption of JD ($\bar{x} = 1.34 \pm 0.05$ [SE] g) was significantly ($F = 58.1$; 1, 18 df; $P < 0.00001$) greater than consumption of NdC (0.84 ± 0.05). Also, there were significant ($F = 34.4$; 5, 90 df; $P < 0.0001$) differences in overall consumption among the 6 maturity dates (Fig. 2), with the lowest and highest consumption occurring for 5 and 25 DAB samples, respectively. As in the aviary tests, patterns of consumption in relation to maturity differed somewhat for the 2 varieties (i.e., the 2-way interaction between varieties and maturity dates was significant [$F = 17.7$; 5, 90 df; $P < 0.0001$]). Tukey's HSD tests revealed that at 5 DAB, consumption of NdC and JD was equivalent and low (Fig. 2). As DAB increased, so did consumption, but increases in consumption were greater for JD than for NdC.

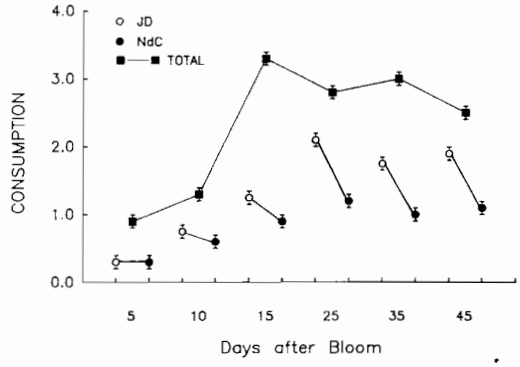

Fig. 2. Mean consumption of Neagra de Cluj (NdC) versus Jacques Discovery (JD) seeds and overall consumption at 6 maturities (DAB) in laboratory 2-hour 1-choice tests. Capped vertical bars represent standard errors of the means.

DISCUSSION AND MANAGEMENT IMPLICATIONS

The results of field, aviary, and laboratory tests support previous findings (Dolbeer et al. 1986) that commercial oilseed varieties are preferred to NdC. However, when oilseed varieties become unavailable, or when birds are numerous, NdC will be damaged. Field data also suggest that avoidance of NdC could vary among avian species. Damage to NdC was high at Ottawa National Wildlife Refuge, where red-winged blackbirds were the most numerous species, but low at the Erie County site, where finches were most abundant. Perhaps the larger size of the NdC seeds compared to JD (Dolbeer et al. 1986) made them more difficult to extract and open for the smaller finches than for the blackbirds. Alternatively, or in addition, laboratory studies have suggested that species (and sex) differences may exist among passerines in sensitivity to a variety of simple tastants (J. E. Espaillat, Monell Chem. Senses Cent., Philadelphia, Pa., and J. R. Mason, unpubl. data; J. R. Mason, unpubl. data). Red-winged blackbirds are relatively insensitive to tannins, a category of substances related to the anthocyanins that are present in NdC (Mason et al. 1986).

From a management perspective, the present results are consistent with the view that varietal resistance represents a potentially viable approach for the control of bird depredation in sunflowers. However, ≥3 issues remain for investigation. First, the factors mediating avoidance of NdC should be clarified. A previous investigation suggested that anthocyanins in NdC cause repellency (Mason et al. 1986). However, anthocyanin and lipid analyses of samples collected during the present investigation (Bullard et al. 1989) suggest that oil content may be an important factor in the preference exhibited by red-wings for JD over NdC sunflowers. Although NdC showed much higher levels of anthocyanins in the hulls (>5%) than did JD (<0.2%), NdC also showed much lower oil content in the achenes (33%) compared to JD (49%) (Bullard et al. 1989). Thus, it is possible that the birds merely exhibited a preference for higher oil level and not an avoidance of anthocyanins. Regardless of the specific factors responsible for the reduced preference for NdC, they appear to be inherent in the seed and not in the vegetative morphology of the plant (Parfitt 1984). The same differences in preference were seen in the field and aviary (with seeds in heads) and in the laboratory (with seeds in cups).

Second, even if NdC avoidance is a result of anthocyanins and not oil, this repellency may not substantially reduce bird depredation. Cummings et al. (1987) report that most (66%) bird damage to sunflower in North Dakota occurs prior to 15 days after anthesis (approx 22 DAB), when biomass/seed is low, and the number of seeds consumed/bird is high. Our aviary results were consistent with this finding, showing that maximum seed loss occurred at 10 and 15 DAB. However, not until later in development (25–35 DAB) are substantial (>1%) amounts of anthocyanin present in NdC (Bullard et al. 1989).

Finally, NdC achene yields are substantially below those of commercial sunflower varieties (Dolbeer et al. 1986). Anthocyanins in NdC can be marketed as food dye (Vaccari et al. 1982) and provide an additional market for growers,

but the problem of low achene numbers/head needs to be addressed if NdC is to be accepted by growers. Cooperative research among plant breeders, plant chemists, and vertebrate pest specialists will be needed to clarify the roles played by anthocyanins and other factors in determining bird feeding preferences in sunflowers.

LITERATURE CITED

BESSER, J. F. 1978. Birds and sunflower. Pages 263–278 *in* J. F. Carter, ed. Sunflower science and technology. Am. Soc. Agronomy, Crop Sci. Am., Soil Sci. Soc. Am., Inc., Madison, Wis.

BULLARD, R. W., P. P. WORONECKI, R. A. DOLBEER, AND J. R. MASON. 1989. Biochemical and morphological characteristics in maturing achenes from purple-hulled and oilseed sunflower cultivars. J. Agric. Food Chem. 37:In Press.

CUMMINGS, J. L., J. L. GUARINO, C. E. KNITTLE, AND W. C. ROYALL. 1987. Decoy plantings for reducing blackbird damage to nearby commercial sunflower fields. Crop Prot. 6:56–60.

DOLBEER, R. A. 1975. Comparison of two methods for estimating bird damage to sunflowers. J. Wildl. Manage. 39:802–806.

———, P. P. WORONECKI, R. A. STEHN, G. J. FOX, J. J. HANZEL, AND G. M. LINZ. 1986. Field trials of sunflower resistant to bird depredation. N.D. Farm Res. J. 43:21–24, 28.

MASON, J. R., M. A. ADAMS, R. A. DOLBEER, R. A. STEHN, P. P. WORONECKI, AND G. J. FOX. 1986. Contribution of seed hull characteristics to resistance of sunflower to blackbird damage. N.D. Farm Res. J. 43:16–20.

———, AND R. F. REIDINGER. 1982. Observational learning of food aversions in red-winged blackbirds (*Agelaius phoeniceus*). Auk 99:548–554.

MEANLEY, B. 1965. The roosting behavior of the red-winged blackbird in the southern United States. Wilson Bull. 77:217–228.

PARFITT, D. E. 1984. Relationship of morphological plant characteristics of sunflower to bird feeding. Can. J. Plant Sci. 64:37–42.

VACCARI, A., P. G. PIFFERI, AND G. ZACCERINI. 1982. Anthocyanins in sunflower (*Helianthus annus*). J. Food Sci. 47:40–42.

WINER, B. J. 1962. Statistical principles of experimental design. McGraw-Hill Book Co., New York, N.Y. 672pp.

Received 23 May 1988.
Accepted 19 January 1989.