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GHOLSON, LARRY ESTIE
THE ATTRACTION OF AGROTIS IPSILON (HUFNAGEL)
LARVAE TO BAITS.

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The attraction of *Agrotis ipsilon*

(Hufnagel) larvae to baits

by

Larry Estie Gholson

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INTRODUCTION

The black cutworm, *Agrotis ipsilon* (Hufnagel) is a cosmopolitan pest, often affecting economically important crops (Bethune 1908, Chamberlin and Madden 1942, Chaudhuri 1953, Crumb 1929, Odiyo 1975, Rings and Arnold 1976, Rings *et al.* 1974). In the American midwest, the black cutworm is an important but sporadic pest of young corn and, more rarely, soybeans (Davis 1952, Gould 1953, Lilly 1950, Sechriest and Sell 1968).

Attempts to determine the overwintering stage and habitat of the black cutworm in the midwest have been unsuccessful (Carey and Beegle 1975). Lacking this knowledge, researchers have not been able to predict location and intensity of black cutworm infestations other than to suggest a general preference for poorly drained, low-lying fields (Beirne 1971, Metcalf *et al.* 1962).

Prophylaxis is not a preferred method for black cutworm control due to the sporadic nature of outbreaks and the lack of registered insecticides for such use. Emergency treatment of infested fields is the technique of preference for black cutworm control today.

Both sprayable and pelleted formulations are used in the midwest and both have different advantages. Spray applications are less expensive when applied at the recommended dosage but they should be banded over the row to get adequate control. While this method is recommended (Stockdale 1977, Stockdale *et al.* 1976), the grower is seldom able to adapt ground equipment to apply a narrow banded spray over the row. Consequently, most treatments are flown on and in order to obtain control equal to that of banded treatments, higher than recommended doses are applied. This places excessive material in the field and raises the cost of the spray application.

Bait treatment of black cutworm infested fields has been successful but bait is expensive and often not manufactured in enough quantities to supply the growers' needs in problem years. One great advantage of baits is that, under broadcast conditions, a much smaller amount of insecticide is placed in the field.

Only one bait formulation is currently recommended for use against black cutworms in corn and it is my belief that we can use alternative organic fillers to increase the attractancy of the bait and, hopefully, decrease costs.

The purpose of this study was to investigate alternative materials for use as bait against black cutworms. A variety of organic baits were intensively screened for attractiveness to black cutworms in the laboratory. Next, population dispersal and bait attractiveness studies were conducted in the field. Extensive greenhouse experiments were conducted to further define bait preferences and to study the effects of photoperiod on feeding behavior.

REVIEW OF LITERATURE

The Black Cutworm, *Agrotis ipsilon* (Hufnagel)

Rings *et al.* (1974) compiled the numerous synonyms of the black cutworm. While *Agrotis ipsilon* (Hufnagel) is the currently preferred choice, a number of references cite *Agrotis ypsilon* which is derived from the description of *Noctua ypsilon* by R. A. von Rottenberg in 1776. Other synonyms which have been used include *Agrotis suffusa* (Schiffermiller), *Agrotis telifera* (Harris), *Exarnis ypsilon* (Hubner), *Peridroma suffusa* (Butler), *Phalaena ypsilon* (Cramer), *Rhyacia ypsilon* (Rottenberg) and *Scotia ypsilon* (Hufnagel).

In Great Britain, the common name is the dark sword grass (moth). The black cutworm is also variously called the ypsilon dart, lance rustic and the greasy cutworm (Rings *et al.* 1974).

Maxwell-Lefroy and Ghosh (1907) gave a very detailed biology of the black cutworm under field conditions in India. Dependent upon environmental conditions, developmental times ranged from 35 to 63 days. Newly hatched larvae curled up and fell to the ground when the plant upon which they rested was shaken. Feeding then continued on dead leaves and other detritus on the ground as the larvae would not climb up the plant. The authors felt that the newly emerged larvae were most often found upon the ground where they lived under fallen plant material. As they matured, they moved to cracks and holes in the ground and nocturnally fed upon plants by cutting stems at or just above the ground level. Cut branches were sometimes observed being drawn into holes apparently for consumption at the larvae's leisure. Cabbages were often bored into from below and the larvae would be found in the bore hole. There were generally 6 to 7 larval molts. Summer generations developed in half the time required by winter generations. Pest activities were generally confined to four months between December amd March although moths could be captured through the year. This coincides with the wet season and outbreaks were noted to be prevalent in fields which had been flooded the previous season.

Satterthwait (1933) approached black cutworm development in a much more controlled manner. He observed 3 generations at Webster Grove, Missouri and felt cool temperatures retarded growth while warm temperatures accelerated growth. Most larvae underwent 5 molts but a substantial number underwent 6 and a few went through 7 molts. Food intake was noted to greatly increase in the later instars.

A number of recent investigations have given a range in developmental times (Abdel-Gawaad and El-Shazli 1971a, Harris et al. 1962b, Luckmann et al. 1976, Mangat 1971, Nasr and Naguib 1963). These times were strongly determined by the temperature and relative humidity under which the cohorts were run. High temperatures enhanced rate of growth, while low temperatures slowed growth. Optimal relative humidity appears to lie between 75% and 80%. Aliev and Akhmedov (1972) delineated the preferred soil types inhabited by larvae in the region of Azerbaidzhan, U.S.S.R.

Archer and Musick (1976) demonstrated a strong negative phototropism among the later instars, an observation common to that of Maxwell-Lefroy and Ghosh (1907). Busching and Turpin (1976) demonstrated feeding preferences of black cutworm larvae. These included a number of winter annual weeds commonly found in the American midwest, curled dock (*Rumex crispus* L.), bluegrass (*Poa pratensis* L.), lambsquarters (*Chenopodium album* L.) and yellowrocket (*Barbarea vulgaris* L.). Ovipositional preferences of the adult female include some of these same weeds (Busching and Turpin 1977), giving a strong implication that damage to crops may well be due to the larvae moving from a preferred host (weeds) to the crop as the first is either depleted by the black cutworm or removed by crop management.

Oku and Kobayashi (1973) observed gravid females ovipositing directly on plant parts. Young, succulent seedlings were strongly preferred. If the crop plant, ladino clover, had fully developed cotyledons the moths preferred to oviposit on a number of weeds. They suggest the morphological unsuitability of a number of crop plants which do suffer black cutworm damage indicates oviposition on succulent weeds. As the larvae mature, they migrate to the crop plant. In regards to moth preference for moist soil, the authors felt it was not the moisture that was directly attractive, but the increased sprouting of weeds and grasses.

Swier *et al*. (1976, 1977) studied mating behavior and found most mating to occur between 2400 and 0300 (CST). Four day old females were most attractive and mating generally occurred 4 days after female emergence. Oviposition began 3 days after mating and peaked at 6 days under laboratory conditions of $24 \pm 1^{\circ}$ C and $70 \pm 5\%$ relative humidity.

Abdel-Gawaad and El-Shazli (1971a) listed females as laying from 386 to 754 eggs while Nasr and Naguib (1963) listed females as laying from 143 to 826 eggs. Other reports in the literature range from 30 to 3000 eggs per female (Odiyo 1975).

The sporadic nature of black cutworm infestations has led a number of researchers to develop rearing techniques which enable them to artificially infest experimental plots. Early workers reared larvae for life history studies on a variety of plants (Crumb 1929, Satterthwait 1933). Bretherton (1969) tried to rear a generation from field collected moths. Eggs were laid and the larvae were fed dandelion and lettuce but adults from this generation did not mate and the colony died out. Harris *et al*. (1958) described a successful mass rearing technique using clover as the larval food source. Mangat (1970) and Reese *et al*. (1972) provided a breakthrough in terms of the number of larvae which could be mass reared by using artificial diets to rear larvae.

Distribution and Hosts of the Black Cutworm

A. ipsilon is a species of near-cosmopolitan distribution (Odiyo 1975). Rings *et al*. (1974) and Rings and Arnold (1976) present annotated bibliographies which include a good number of articles on distribution and hosts of the black cutworm.

The black cutworm is a hardy moth and is believed to be a migratory pest in Japan (Oku *et al*. 1970), India (Maxwell-Lefroy and Ghosh 1907, Woodhouse and Fletcher 1912), Israel and the mideast in general (Odiyo 1975, Rivnay and Yathom 1964) and England (Bretherton 1969).

Elsewhere in the world, the black cutworm is considered an around-the-year inhabitant either with continuous generations or a diapausing stage. The nature of the diapausing stage is subject to controversy because a definitive diapausing stage has not been scientifically determined (Carey and Beegle 1975).

Records of black cutworm infestations in crops date far back in the memory of man. Howard (1930) cites ancient Egyptian papyri which note infestations of "worms" thought by several authorities to be A. ipsilon. One appropriate sentence translates to, "The worm ate half the crop and the hippopotami ate the other half."

In England there are few reported damaging infestations of A. ipsilon. This generally holds true for Europe. Outbreaks do occur on the continent, apparently when environmental conditions such as warm weather, unseasonably heavy rainfall, and flooding occur before the growing season. Germany suffered a serious outbreak in 1952 with potatoes, beets and carrots suffering heavy damage (Nolte and Fritzsche 1953). Meszaros and Nagy (1968) reported that Hungary had not suffered economic damage from black cutworms until 1965 which was a flood year. During the growing season, crops on the flood plain, notably cabbage, beans and corn, suffered heavy damage. A similar outbreak was reported by Popov (1963) in Bulgaria where corn and tobacco were heavily infested.

Pelekassis (1962) and Soueref (1965) comment on the destruction of small grain crops in Greece by A. ipsilon. Guest (1931) described heavy damage to cotton seedlings in Iraq and Osman (1928) listed the black cutworm as one of the most important pest species on tobacco in

Turkey. Rivnay (1963) called the black cutworm the "worst cutworm in Israel" where it has been a serious pest of corn and other grains.

Gentry (1965) listed general crops affected by black cutworms throughout north Africa and the Mideast. These include vegetables, grains, cotton and tobacco. Irrigated lands with alfalfa have often been infested in Saudi Arabia (Abu Yaman 1966). Hassanein et al. (1971), Loutfy (1959), Loutfy et al. (1970) and Nasr et al. (1973) verify the acute damage done to cotton seedlings and other crops in the flood plain of the Nile. Jack (1913) considered the black cutworm a serious pest of tobacco in Rhodesia and Blair (1968) identified the black cutworm as an economically important general pest of Rhodesian crops.

Historically, black cutworms have been a problem on a number of crops in India, principally potato but also opium, gram (chickpea) and tobacco (Maxwell-Lefroy and Ghosh 1907, Woodhouse and Fletcher 1912). More recently, Chaudhuri (1953) and Purohit et al. (1971) have reported serious infestations in potato fields.

In Malaysia, the black cutworm has caused economic damage to vegetable crops (Corbett and Pagden 1941) and tobacco (Miller 1933). This species is also a pest of tobacco in Fiji (Lever 1940). Calora et al. (1968) reported damaging populations infesting cabbage in the Philippines.

Frequently the black cutworm has been a pest of field crops in Australia (Froggatt 1923, Smith 1939). It has been a particularly troublesome pest of cotton seedlings in New South Wales (Gurney 1924) and alfalfa in Queensland (Jarvis and Smith 1946, Smith 1939).

Liu (1936) describes the black cutworm as one of the most destructive and widely distributed pests of cotton seedlings in China. Kuwayama _et al_. (1960) list this species as a common insect in Japan and occasionally a very serious pest of sugar beets, flax, legumes, onions and cabbage. Also in Japan, Oku and Kobayashi (1973) and Oku _et al_. (1970) describe the black cutworm as causing severe damage to newly planted artificial grasslands, some field crops and vegetables.

In South America, the black cutworm has been a periodic pest of peas in Chile (Olalquiaga 1953) and a severe pest of tomato and potato in Sao Paulo, Brazil (Pigatti 1959). In Peru it has been a pest of cotton in several regions (Valencia and Valdivia 1973).

The black cutworm is common throughout North America and Hawaii and a number of authors list quite general crop preferences (Bethune 1908, Davidson and Peairs 1966, Frost 1955, Gibson 1912, Harris and Mazurek 1961, Thompson 1935). In the American midwest, corn has been subject to very severe damage by this pest (Bigger and Blanchard 1959, Davis 1952, Goncales 1964, Gould 1953, Harris _et al_. 1949).

Periodically, black cutworms have been severe pests of tobacco grown in the United States and Canada (Anderson 1902, Begg _et al_. 1963, Chamberlin and Maddin 1942). Cole crops also appear to have a strong attraction for black cutworms and a number of areas have experienced outbreaks in these crops (Garman 1904, Gibson 1912, Reid and Cuthbert 1957).

Lettuce grown in California (Knott and Travernetti 1944) and New York (Herrick 1926, Smith 1910) has been subject to black cutworm attack. Celery in Utah (Knowlton 1958) and Florida (Wilson and Hayslip 1951) has also been subject to serious damage by this pest.

Ingram et al. (1939) reported on damage to sugarcane in Florida and Baver (1956) reported severe damage to cane seed pieces on Kaui. Also in Hawaii, Chung (1923) reported serious damage to sweet potato vines by nocturnally active black cutworms.

Knutson (1944) listed the black cutworm as the most destructive cutworm in Minnesota, citing damage to strawberry beds in particular. Forbes and Hart (1900) also listed damage to strawberries as well as apple and grape seedlings and sugar beets in Illinois. Saunders (1883) listed the black cutworm as a general pest of strawberries. It has also been declared a pest of grape, feeding on buds and shoots, in California (Lockwood and Gammon 1949, Smith and Stafford 1955).

When winter flooding occurred later than normal in Massachusetts, black cutworms have been reported as serious pests of cranberries (Franklin 1919, 1945). Sanderson (1905) lists the black cutworm as a pest of cotton in Texas. It is also a pest of southern peas in Florida (Wilson and Kelsheimer 1955) and onions in New York (Eckenrode et al. 1976).

While this is not a complete review of every report on every crop affected by biack cutworms, the literature readily reflects the opportunistic nature of this species and its involvement with the crops of man on a worldwide basis.

Control of the Black Cutworm

The literature reveals methods of control of *A. ipsilon* as varied as the crops which this pest attacks. Early control practices were cultural in nature and the advantage of clean or weedless fields was widely recognized (Anderson 1902, Davis 1919, Symons 1905). Woodhouse and Fletcher (1912) felt that organized handpicking of black cutworm larvae from the field was more effective than other cultural practices or baiting. This observation was made in India where the labor force permitted such intensive use of man power. These same authors felt that the trapping of adults in Andres-Maire traps aided in the control of outbreaks. Their main concern was in having enough traps set up in time to catch an adequate proportion of the adult cutworm population to prevent larval damage to crops.

Saunders (1883) felt that for garden control naturally occurring parasites usually did a good job. When the problem got out of control he suggested hand collecting first, then application of air-slacked lime, ashes or powdered hellebore. As a last resort, Paris green at 1 teaspoon per bucket of water was the suggested method of control.

A variety of poison baits have been favored for black cutworm control since the latter years of the nineteenth century. There does not appear to be any reference to chemical control of the black cutworm preceding those years. According to Morrill (1919), the first published reference to poison bait for use specifically against black cutworms was by J. B. Smith in 1894.[1]

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[1] Insect Life, 7:191. From a paper read before the American Association of Economic Entomologists, August, 1894.

Wheat bran has been a strongly preferred bait filler since the early days of baiting. Davis and Turner (1918) found wheat bran superior to sawdust filler when used as bait for black cutworm control. Anderson (1902) suggested a recipe for cutworm control in tobacco: 1 lb Paris green, 40 lb wheat bran and 2 qt cheap molasses. Application consisted of 1 teaspoon sprinkled on each planted hill. Bethune (1908) also recommended a poison bait but his recipe had only 1/2 lb Paris green and 50 lb of wheat bran. Two quarts of cheap molasses mixed in 1 gal of warm water were used to moisten the mixture. Thompson (1926) suggested two stronger formulations for cutworm control: 1) 25 lb wheat bran, 1/2 lb salt, 1 lb white arsenic or Paris green and 1 pt syrup or brown sugar; 2) 16 lb wheat bran, 1 lb sodium flouride, 2 qt molasses and 2 qt water.

Herrick (1926) used 1 lb Paris green or 1 1/2 lb arsenate of lead per 20 lb wheat bran and 2 qt molasses. He then added two lemons, finely chopped for added attraction. Lyle (1927, 1928, 1929) recommended 1 lb toxicant per 50 lb wheat bran and found Paris green to be superior to sodium fluosilicate. Kelsheimer (1944) found rice bran superior to wheat bran and citrus pulp in terms of cost and attraction to larvae. He added molasses for attraction and texture. The performances of the toxicants he used were: sodium fluosilicate > calcium arsenate > cyrolite > Paris green. Chamberlin and Madden (1942) specifically stated that too much toxicant in the bait mixture made it unattractive to black cutworms and used a 1 lb Paris green to 50 lb wheat bran (with molasses and water to moisten) mixture. However, Kamel and Shoeb

(1958) stated that the higher the rate of toxicant used in their baits, the better the control obtained.

The matter of molasses and its attraction to black cutworm larvae is also controversial. Morrill (1919) found molasses had no effect when added to bait for use against two species of locusts and black cutworms. Chamberlin and Madden (1942) found molasses had no effect on Paris green bait used against black cutworm larvae in tobacco fields. This observation was confirmed by Hayslip (1944) who suggested substituting SAE 20 oil for its usefulness as a "sticker" to hold the bait together.

In all cases the early literature agreed that moist baits worked best when freshly mixed and the authors recommended application during twilight in order to take advantage of the nocturnal feeding habits of the larvae.

The development and commercial exploitation of the synthetic organic insecticides in the early 1930's led to the use of a variety of materials against black cutworms as well as many other pests. Chlorinated hydrocarbon insecticides such as DDT, BHC, toxaphene, dieldrin, aldrin, endrin, lindane, heptachlor and chlordane were all popular materials due, in large part, to their long residues in the soil (Bigger and Blanchard 1959, Lilly 1950, Wressell 1965). Some organophosphorous and carbamate insecticides have also been used or tested against black cutworms, including: diazinon, phorate, trichlorfon, dimethoate, parathion, disulfoton, diethyl trichloropyridyl phosphorothioate, carbaryl, mercaptodimethur, carbofuran, methomyl and aldicarb (Apple 1968, Harris *et al*. 1973, Hofmaster *et al*. 1967, Pigatti 1959, Sechriest and Sell 1968). Considerable disagreement exists in the literature as to which materials are most suitable for black cutworm control. Harris (1972) felt the erratic performances of many soil insecticides were due to soil type, organic content of the soil, temperature, moisture, desired period of residual and the nature of the insect populations themselves.

Lilly (1950) found toxaphene effective against the black cutworm in corn when applied by air at 2 lb/acre. Randolph (1956) used a mixture of toxaphene and DDT (2/1), applied at 3 lb/acre and attained much better control than with parathion or malathion sprays. Aldrin and heptachlor treatments, broadcast sprayed at 1 1/2 lb/acre gave good control in corn as did aldrin sprayed over the row at 1 lb/acre (Bigger and Blanchard 1959). Wressell (1965) found the following order of control of black cutworms in artificially infested tobacco plots; endrin > aldrin=dieldrin=heptachlor > DDT=trichlorfon > carbaryl. These were all broadcast sprayed at 1.5 lb/acre except for endrin which was applied at 0.6 lb/acre. Samy (1964) showed that DDT and lindane sprays caused acceptably high mortalities in black cutworm and other cotton pest eggs. Chaudhuri (1953) obtained considerably better control with a 5% DDT+ pyrethrin dust than with a 5% toxaphene dust on potatoes in India. However, Kamel and Shoeb (1958) obtained better control of black cutworm populations in cotton seedlings with both 50% aldrin WP and 60% toxaphene sprays than with a DDT+lindane (30/9) spray mixture.

When a 2.5% aldrin treatment failed to control black cutworms on a variety of vegetable crops in Sao Paulo, Brazil, 10% carbaryl was the best emergency spray followed by 10% DDD and 10% DDT. Totally unacceptable results were obtained under laboratory conditions using vacuum dusting applications of: 10% toxaphene, 1% EPN, 1.5% endrin, 2% azinophos-methyl, 2% lindane, 1% parathion, 2.5% heptachlor and 10% chlordane (Pigatti 1959).

Loutfy (1959) found toxaphene 10G and 60 EC unsatisfactory when applied both at high and low rates in cotton. Dieldrin 20 EC had the best results when applied at 7.5 kg/acre but was unsatisfactory at lower rates. DDT 30 EC performed adequately both at high and low rates. All treatments were incorporated into the soil prior to planting. Endrin 2G and heptachlor 10G gave 50% and 59% control when applied to cotton at 15 kg/acre (Loutfy _et al_. 1970). Toxaphene 10G performed poorly when used on tobacco in India (Thimmaiah _et al_. 1972). Also unacceptable in the same experiment were: heptachlor 20 EC, endrin 20 EC, toxaphene 20 EC, heptachlor 10G, endrin 2G, parathion 2G, DDT 50 WP, carbaryl 10% dust and DDT 10% dust. Acceptable control was obtained with endosulfan 35 EC > aldrin 30 EC > parathion 46.7 EC > heptachlor 6% dust > carbaryl 50 WP. Abdel-Gawaad and El-Shazli (1971b) applied 6 chemicals at 6 rates to confined black cutworms and obtained the following results: phorate 40% dust > disulfoton 50% > lindane 25 WP > carbophenothion 45.8 EC > DDT 50 WP > heptachlor 5G. The rates at which these materials were applied to the soil were 4, 6, 8, 10, 12 and 14 p.p.m.

In 1949, outbreaks of black cutworms in Iowa were not adequately controlled by DDT and chlordane dusting or by poison baits (Granovsky

1949, Harris et al. 1949). Begg and Harris (1959) found that aldrin incorporated, in a variety of ways, into fields of flue cured tobacco did not control black cutworms until at least 3 days elapsed from time of treatment. Begg et al. (1963) further found that incorporation of the following insecticides did not control cutworm outbreaks for at least 7 days: endrin, aldrin, dieldrin, heptachlor, DDT, trichlorfon, guthion and carbaryl. Kulash (1947, 1949) found that fields treated 9 weeks prior to planting suffered more damage than fields treated 2 weeks before planting. Regardless, none of the following treatments provided adequate control although each was applied at a variety of rates: benzene hexachloride+DDT dust, chlordane, benzene hexachloride, DDT. Gould (1953) stated that, in Ohio, no one material was uniformly effective against the black cutworm. Although the black cutworm has generally been susceptible to the cyclodienes, DDT and toxaphene have been the lowest performing members of this group (Harris et al. 1962a).

Carbaryl and trichlorfon have bioassayed higher than both DDT and toxaphene but lower than endrin, aldrin and heptachlor (Harris and Mazurek 1961, Harris et al. 1973). In low organic, sandy soil, heptachlor epoxide, a natural metabolite of heptachlor, is effective against black cutworms but not in high organic soils (Harris and Sans 1972). The removal of heptachlor and chlordane from the market has not apparently been a matter of economic importance to growers in Missouri in light of the questionable performances of these two materials (Collins and Headley 1976).

Hassanein et al. (1971) found a wide variety of control in cotton using carbaryl (54 to 64% control) and trichlorfon (38 to 77% control). Hofmaster et al. (1967) obtained adequate control of black cutworm populations attacking potato foliage using azinphosmethyl, carbaryl, and DDT treatments. Sechriest and Sell (1968) found methomyl granules to be effective in controlling infestations on corn. Apple (1967) obtained suitable control of artificial infestations in barriered plots with diazinon, aldrin+parathion, carbaryl, carbofuran and phorate. Diazinon at 1 lb/acre and toxaphene at 1 and 2 lb/acre were not satisfactory materials.

Eckenrode et al. (1976) described black cutworm damage to onions and the failure of the following commonly used vegetable insecticides to control artificial infestations of larvae in onions: methomyl, diazinon, parathion, methoxychlor, azinophos-methyl and trichlorfon. It is noted in this article that the experimental synthetic pyrethrins show considerable promise in black cutworm control in onions.

Dimetry and Mansour (1971) have determined that a variety of salt solutions deter feeding of black cutworm larvae on cotton foliage but the effects of the solutions can be detrimental to foliar growth and, ultimately, production. Shaaban et al. (1975) felt that some chemosterilants offered an attractive means to control black cutworm populations.

The use of formulated baits for black cutworm control seems to have become popular in the middle 1960's. Wilson and Kelsheimer (1955) recommended a wet bait using either toxaphene or chlordane but this was not commercially formulated, that is, the applicator had to mix it himself.

Formulated baits are dry, look like rabbit food pellets and generally have small amounts of toxicant in them. Apple (1968) used fresh baits of wheat bran or apple-pomace bran and found that after application, aging decreased the activity of the baits. Carbofuran performed better than carbaryl at 0.84 kg/ha but trichlorfon and endosulfan provided 91.8 and 95% control at 1.12 kg/ha. Sechriest and Sherrod (1973) found a great deal of variation in control between fields but the overall performance of the materials tested ranged as follows: temophos bait > methomyl bait > diethyl trichloropyridyl phosphorothioate bait > carbaryl bait. Rings _et al_. (1973) found that 1 lb of 2% mercaptodimethur bait/1000 ft^2 and 0.5 lb of 5% carbaryl bait/1000 ft^2 killed 32 and 44% of the sixth instar larvar present in artificially infested plots, respectively. This was not judged to be a suitable level of control. In 1976, suitable control was obtained by using 2 lb of 5% carbaryl bait per acre (85% control) but 2% mercaptodimethur bait at 1 and 1.5 lb/acre only gave 40% control.[2]

Sechriest (1968) stated that baits incorporated in the soil, in the manner of some insecticide granules, lost their attractiveness to black cutworm larvae and control was decreased. He also noted that different toxicants performed better on different bait fillers. Sechriest and Sherrod (1977) demonstrated that 5% carbaryl bait on moist soil

[2]Beegle, C. C., 1976. Annual report of insecticide evaluation. Department of Entomology, Iowa State University, Ames, Iowa.

does not have as good a residual as on dry soil. Further, while some moisture must be present to make the bait pellet acceptable to the larvae, the humidity in the air was sufficient to soften the pellet. However, larvae tend to live in moist soil and under moist conditions feed readily at the surface during the night.

On a worldwide scale, the literature reveals an extremely erratic performance by the chemicals which have been used against the black cutworm. This observation, coupled with the irregular appearances of black cutworm populations, negates prophylactic control in most instances.

PART I. LABORATORY STUDIES ON THE ATTRACTION OF BLACK CUTWORM LARVAE TO SEVERAL BAIT MATERIALS

Abstract

An overall tendency for fourth, fifth and sixth instar larvae to feed in a variety of baits was demonstrated. Temperature and relative humidity fluctuations which occurred in the laboratory did not significantly affect the behavior of the larvae. Cotton seed hull pellets were the most attractive and inert glass boiling beads were the least attractive of the materials tested. Moist baits were more attractive than dry or glycol treated baits.

Introduction

A number of methods have been used to control black cutworms and one of the most popular has been the use of poison baits (Anderson 1902, Bethune 1908, Davis and Turner 1918, Lyle 1928, 1929, Sechriest and Sherrod 1973, 1977, Wilson and Kelsheimer 1955). Presently, apple-pomace bran is the only filler used in commerical baits for black cutworm. Apple-pomace and bran are expensive materials. Therefore, this study was undertaken to see if other relatively inexpensive organic fillers would be suitably attractive to late instar black cutworm larvae.

Methods and Materials

A black cutworm colony, established from field collected larvae, was maintained according to the general format described by Reese *et al.* (1972). Fourth, fifth and sixth instar larvae were selected for the screening of the various bait materials. The materials tested included: apple-pomace bran pellets, bran pellets, grape pellets, apple-grape pellets, cotton seed hull pellets, citrus pellets, apple-grape pulp, grape pulp, cornmeal, and inert glass boiling beads. Glass boiling beads were obtained from the Iowa State University Chemistry stores and the cornmeal was obtained from a local grocery store. The other organic materials were by-products of existing industries such as cotton seed oil mills, citrus juicing plants and wineries. All pellets were processed by one formulator[3] with the exception of the cotton seed hulls which came in pellet form from the cotton seed oil mill. The glass beads were used to test whether the larvae would respond to the physical presence of objects as well as to olfactory or other physiological stimuli of the baits.

Each material was tested: dry, wet with 5-10 drops of water and wet with 2 drops of glycol (water and glycol were applied by eyedroppers). Glycol is used as a binder in the process of pelletizing baits and I wished to determine if it displayed any effects upon bait attractiveness. Each of these treated bait combinations was tested against fourth, fifth and sixth instar larvae. Further, all of these combinations were tested with bait distances from the larvae of 2, 4 and 6 cm.

The testing procedure used two 18-cm stainless steel pie pans, one for the bait and one for its concurrently run control. Into each pie pan was fitted one 18-cm qualitative grade filter paper inscribed with

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[3]Manufacturing Division, Hopkins Agricultural Chemical Co., Madison, WI.

a central, 1-cm radius circle, in pencil, and with concentric circles of 3, 5 and 7-cm radii. The filter paper was moistened before placement in the pans because preliminary work revealed the larvae would not readily move on dry filter paper but were quite mobile on wet filter paper.

When the paper was fitted into the pan, ca. 0.25 or 0.5 gm of the appropriate bait material was placed in the central circle. One cutworm, of the appropriate stage, was then placed in each pan at the desired distance (2, 4 or 6 cm) from the bait or empty central circle. The empty central circle served as a control to determine if the cutworm response to baits was random or due to an orientation to the bait. After placement of the cutworms in the two pans, a stop watch was started and the trial allowed to run for 2 minutes. The presence of either larva in the central circle (i.e., a score) of each pan, the time elapsed to reach the central circle and the total time spent there were recorded. Twenty observations (40 larvae) were made for each set of conditions (instar by bait by distance by bait treatment).

Continual observations on a hygrothermograph allowed me to determine if temperature and relative humidity fluctuations significantly affected larval responses. Analyses of variance of the data, including temperature and relative humidity values, were performed using the general linear models procedure for the three dependent variables: number scored, time to score, and time spent in central circle.

Subsequent analyses of variance were run on the number of scores per 20 observations, the means of the times to score per twenty observations. Those factors which had an F-score probability of less than 0.05 were run through a Duncan's multiple range test to determine significant differences.

Results and Discussion

The preliminary analysis of variance using the general linear models procedure was run on complete data sets for apple-pomace bran pellets, citrus pellets, grape pulp and apple-grape pulp. Temperatures in the laboratory varied between 20° and 26.7° C but did not significantly affect the number of larvae that scored, the time to score or the time the larvae spent in the baits. However, at higher temperatures the trend was for cutworms to score more often and spend longer periods in the baits. Relative humidity was not a controllable parameter in the laboratory and varied considerably over the period of time in which this experiment was run (20% to 82%). This did not cause significant variation in terms of number of larvae which scored or how long it took them to score but it did significantly affect how long the larvae stayed in the baits. As relative humidity increased, the larvae remained in the baits for shorter periods of time.

Analysis of the data concerning the number of cutworms which scored per set of treatment combinations indicates that several factors and interactions supplied strong sources of variation (Table 1).

The means of the number of scores between instars were significantly different at the 0.05 level with sixth instars scoring most often ($\bar{x} = 3.5$), and fourth and fifth instars scoring less often, ($\bar{x} = 3.14$ and 3.06 respectively). Means for scoring between distances were all significantly different from each other at the 0.05 level with the greatest number of cutworms scoring when placed 2 cm from the central circle (Table 2).

Greater numbers of larvae scored in cotton baits than in any of the other materials (Table 3). Wet materials were scored in significantly more often than were dry materials (Table 4). Overall, larvae scored significantly more often in baited central circles ($\bar{x}$ = 4.32) than in control central circles ($\bar{x}$ = 2.18). The interactions of bait by instar and bait by distance were significantly different at the 0.05 level (Table 1). Of interest here is that circles containing both cotton and apple-grape pellets had more larvae score in them at 6 cm than did circles containing bran, citrus, grape pulp, apple-pomace bran and cornmeal at 4 cm. Further, at 2 cm circles containing glass beads were scored in least often but were scored in more often than several other baits at 4 and 6 cm. This indicated that the larvae responded to all baits at 2 cm but that the ability of baits to attract larvae beyond 2 cm was highly variable among the organic baits other than cotton seed hull pellets and apple-grape pellets (Table 5).

The analysis of the variable, time-to-score, indicated that it was probably not a good parameter to use in defining the attractiveness of baits under the conditions of this experiment. Table 6 shows that the distance of larval placement from the central circle, the baits themselves, and the bait by instar interaction were all significantly different at the 0.05 level.

The time to score was significantly shorter at 2 cm ($\bar{x}$ = 41.8 sec) than at either 4 cm ($\bar{x}$ = 53.6 sec) or 6 cm ($\bar{x}$ = 54.7 sec). The baits were significantly different from one another in terms of time to score and Table 7 lists the differences based upon a Duncan's multiple range test. Cotton seed hull pellets were the best performing material and cornmeal the poorest.

A number of main effects and interactions were significantly different at the 0.05 level in the analysis of variance for the variable, time spent in baits (Table 8). The time spent in baits was significantly different between instars (Table 9), and the closer the larvae were placed to the baits, the longer they stayed in them. At 2 cm, larvae stayed 28.4 sec; at 4 cm, 25.5 sec; and at 6 cm, 23.6 sec.

Time spent in baits was also significantly different between baits (Table 10). Cotton seed hull pellets received the longest scores and glass beads the shortest scores. The larvae stayed significantly longer in wet baits than in either dry or glycol treated baits (Table 11). Also, the time spent in baits overall was significantly greater (39.6 sec) than the time spent in the central circle of the controls (11.1 sec).

Conclusions

It is possible to show the differences in attraction of various materials to late instar black cutworm larvae under laboratory conditions. The two most important variables which defined differences in attractancy, using the techniques described here, were the number of cutworms which scored in the central circle (or baits) and the amount of time which they spent in the central circle (or baits). Data on these variables indicate that baits attract more larvae than controls and larvae stay significantly longer in areas with baits than in areas without baits (Tables 3 and 10). Under laboratory conditions, moist baits are much more attractive than dry or glycol treated baits (Tables 4 and 11). The observation that larvae spent increasingly less time in baits as the relative humidity increased should be critically examined in future work. The possibility that relative humidity affects the larval preference for wet bait over dry bait also needs to be examined.

Glass beads attracted fewer larvae than all organic materials and were not significantly different from any controls which were run with all the baits (Table 3). Apparently the larvae were not attracted merely by the physical presence of objects in the test pans. Larvae which did enter the center circles with glass beads stayed for significantly shorter periods than in any organic bait. However, larvae stayed significantly longer in glass beads than in the controls with only one exception (Table 10). While the larvae apparently are not attracted to chemically inert glass beads, they do prefer to remain amongst such objects as opposed to staying in the central circle of control pans. The preference for contact with organic baits over glass beads is, however, strongly pronounced.

The distance of larvae from baits did not appreciably affect the length of time larvae spent in baits but increased distance greatly decreased the number of larvae which scored (Table 2).

These data strongly suggest the importance of a uniform distribution of bait pellets in the field due to the great differences in attractancy between 2 cm and greater distances. Some materials, such as cotton seed hull pellets and apple-grape pellets appear superior in attractiveness at 6 cm than the other materials tested while also attracting considerably more larvae when in closer proximity.

Sixth instar larvae scored most often but stayed in the baits less than the fourth or fifth instar larvae (Table 9).

Cotton seed hull pellets were the most attractive material to the larvae in terms of numbers scored, time to score and length of time spent in baits. Inert glass boiling beads were least attractive to the larvae in terms of number scored and time spent in the beads. The larvae also scored well in apple-grape pellets and citrus pellets but they remained in those materials for a shorter time than in the other organic baits. Apple-pomace bran pellets and bran pellets, in terms of numbers scored and length of time spent in the bait, fall into the lower half of the materials tested.

The mediocre performance of apple-pomace bran pellets suggests that they are not the best material for use as a bait against black cutworms. Hopefully one or more of the materials studied here will prove to be an attractive and economical bait for use against black cutworms.

Table 1. Analysis of variance for the number of black cutworm larvae which scored in laboratory baiting experiments

Source of variation	Degrees of freedom	Mean square	F-value
Instar	2	11.82	3.111*
Distance	2	340.25	89.539**
Bait (TA)	9	8.50	2.237*
Dry, wet or glycol (TB)	2	15.51	4.012*
Bait or control (TC)	1	602.46	158.542**
Distance * instar	4	1.71	0.450
TA * instar	18	8.28	2.179**
TB * instar	4	4.28	1.126
TC * instar	2	4.04	1.063
TA * distance	18	5.73	1.508
TB * distance	4	4.53	1.192
TC * distance	2	19.42	5.111**
TA * TB	18	2.50	0.658
TA * TC	9	11.90	3.132**
TB * TC	2	8.26	2.174**
Residual	431	3.80	
Total	527	6.75	

*Significant at the 0.05 level.
**Significant at the 0.01 level.

Table 2. Mean number of 20 black cutworm larvae entering baits and concurrently run controls at 2, 4 and 6 cm

Distance	n[a]	Bait[b]	Control[b]
2 cm	89	6.12 a	2.75 d
4 cm	87	4.06 b	1.80 e
6 cm	88	3.39 c	1.33 e

[a]Number of trials using 20 larvae/trial.

[b]Means not followed by the same letter are significantly different at the 0.05 level using Duncan's multiple range test.

Table 3. Mean number of 20 black cutworm larvae entering circles containing different baits and their controls

Material	n[a]	Bait[b]	Control[b]
Cotton seed hull pellets	27	5.67 a	2.67 d
Apple-grape pellets	29	4.79 ab	1.97 d
Citrus pellets	27	4.74 ab	1.81 d
Grape pulp	28	4.68 ab	1.93 d
Grape pellets	27	4.56 ab	1.89 d
Apple-pomace bran pellets	27	4.15 bc	2.26 d
Apple-grape pulp	27	4.11 bc	2.44 d
Bran pellets	27	4.07 bc	2.00 d
Cornmeal	27	3.04 c	2.15 d
Glass boiling beads	18	2.83 cd	3.00 cd

[a]Number of trials using 20 larvae/trial.

[b]Means not followed by the same letter are significantly different at the 0.05 level using a Duncan's multiple range test.

Table 4. Mean number of 20 black cutworm larvae entering dry, wet and glycol-treated baits and concurrently run controls

Treatment	n[a]	Bait[b]	Control[b]
Wet	81	4.89 a	2.30 c
Glycol	91	4.27 b	2.12 c
Dry	92	3.86 b	2.14 c

[a]Number of trials using 20 larvae/trial.

[b]Means not followed by the same letter are significantly different at the 0.05 level using a Duncan's multiple range test.

Table 5. Mean number of 20 black cutworm larvae which entered circles containing different baits at 2, 4 and 6 cm

Material	n[a]	Distance (cm)	Mean No. Scores[b]
Apple-grape pulp	18	2	5.39 a
Cotton seed hull plt.	18	2	5.33 a
Grape pulp	18	2	5.28 a
Bran pellets	18	2	5.28 a
Citrus pellets	18	2	5.06 a
Apple-pomace bran plt.	18	2	5.00 a
Cotton seed hull plt.	18	4	4.30 ab
Apple-grape pellets	22	2	4.27 ab
Cornmeal	18	2	4.06 abc
Grape pellets	18	2	3.94 abcd
Glass boiling beads	12	2	3.75 abcde
Grape pellets	18	4	3.39 bcde
Apple-grape pulp	18	4	3.28 bcde
Apple-grape pellets	18	4	2.94 bcdef
Cotton seed hull plt.	18	6	2.83 bcdef
Glass boiling beads	12	4	2.75 bcdefg
Apple-grape pellets	18	6	2.72 cdefg
Bran pellets	18	4	2.67 cdefg
Citrus pellets	18	4	2.61 cdefg
Grape pulp	18	4	2.50 defg
Apple-pomace bran plt.	18	4	2.50 defg
Grape pellets	18	6	2.33 efg
Cornmeal	18	4	2.28 efg
Grape pulp	20	6	2.25 efg
Glass boiling beads	12	6	2.25 efg
Citrus pellets	18	6	2.16 efg
Apple-pomace bran plt.	18	6	2.11 efg
Cornmeal	18	6	1.44 fg
Apple-grape pellets	18	6	1.17 g
Bran pellets	18	6	1.17 g

[a]Number of trials run with 20 larvae/trial.

[b]Means not followed by the same letter are significantly different at the 0.05 level using Duncan's multiple range test.

Table 6. Analysis of variance for the time to score of black cutworm larvae in laboratory baiting experiments

Source of variation	Degrees of freedom	Mean square	F-value
Instar	2	1126.52	2.359
Distance	2	8572.69	17.949**
Bait (TA)	9	1414.46	2.962**
Dry, wet or glycol (TB)	2	358.57	.751
Bait or control (TC)	1	351.97	.737
Distance * instar	4	110.65	.232
TA * instar	18	855.55	1.791*
TB * instar	4	907.09	1.791*
TC * instar	2	55.40	.116
TA * distance	18	473.05	.990
TB * distance	4	465.91	.976
TC * distance	2	158.77	.332
TA * TB	18	511.59	1.071
TA * TC	9	147.42	.309
TB * TC	2	175.39	.367
Residual	384	477.61	
Total	480	535.95	

*Significant at the 0.05 level.
**Significant at the 0.01 level.

Table 7. Overall mean times[a] for black cutworm larvae to enter baits (time to score)

Material	Time (seconds)[b]
Cotton seed hull pellets	39.93 a
Bran pellets	45.54 ab
Apple-grape pellets	45.97 ab
Glass boiling beads	46.78 ab
Grape pellets	50.09 bc
Grape pulp	51.49 bc
Apple-grape pulp	51.79 bc
Apple-pomace bran pellets	52.08 bc
Citrus pellets	53.78 bc
Cornmeal	59.41 c

[a]Means based only on those larvae which scored.

[b]Means not followed by the same letter are significantly different at the 0.05 level using Duncan's multiple range test.

Table 8. Analysis of variance of the time spent in baits for black cutworm larvae in laboratory baiting experiments

Source of variation	Degrees of freedom	Mean square	F-value
Instar	2	5146.41	24.372**
Distance	2	961.07	4.551*
Bait (TA)	9	607.20	2.876**
Dry, wet or glycol (TB)	2	998.33	4.728**
Bait or control (TC)	1	97516.74	461,814**
Distance * instar	4	238.29	1.128
TA * instar	18	304.49	1.442
TB * instar	4	196.88	.932
TC * instar	2	1802.95	8.538**
TA * distance	18	183.70	.870
TB * distance	4	60.80	.288
TC * distance	2	546.20	2.587
TA * TB	18	423.01	2.003**
TA * TC	9	632.18	2.994**
TB * TC	2	776.08	3.675*
Residual	384	211.16	
Total	480	475.38	

*Significant at the 0.05 level.
**Significant at the 0.01 level.

Table 9. Overall means[a] of the times spent in baits and concurrently run controls for fourth, fifth and sixth instar black cutworm larvae

Instar	Time (seconds) Bait[b]	Control[b]
4	48.65 a	13.78 d
5	38.94 b	9.87 d
6	31.01 c	9.52 d

[a]Means based upon only those larvae which scored.

[b]Means not followed by the same letter are significantly different at the 0.05 level.

Table 10. Mean[a] for the times spent in different baits and their controls by black ctuworm larvae

Material	Time (seconds) Bait[b]	Control[b]
Cotton seed hull pellets	50.58 a	10.05 e
Grape pulp	45.71 ab	8.77 e
Cornmeal	41.54 bc	11.45 e
Apple-grape pulp	40.92 bc	12.34 e
Grape pellets	39.01 bc	10.87 e
Apple-pomace bran pellets	38.96 bc	10.41 e
Bran pellets	38.39 bc	10.66 e
Citrus pellets	38.25 bc	16.15 de
Apple-grape pellets	33.27 c	8.26 e
Glass boiling beads	22.85 d	12.02 e

[a]Means based upon only those larvae which scored.

[b]Means not followed by the same letter are significantly different at the 0.05 level using a Duncan's multiple range test.

Table 11. Means[a] for the times spent in wet, dry and glycol treated baits by black cutworm larvae

Treatment	Time (seconds) Bait[b]	Control[b]
Wet	45.17 a	11.45 c
Glycol	37.25 b	11.73 c
Dry	37.01 b	10.11 c

[a]Means based upon only those larvae which scored.

[b]Means not followed by the same letter are significantly different at the 0.05 level using Duncan's multiple range test.

PART II. FIELD STUDIES ON THE ATTRACTION OF BLACK CUTWORM LARVAE TO SEVERAL BAIT MATERIALS

Abstract

Under field conditions with 2-leaf stage field corn (B73 x Mo17), fourth, fifth and sixth instar black cutworm larvae responded to different organic baits. Grape, apple-grape and bran pellets attracted significantly more larvae than did apple-pomace bran, citrus, cornmeal or cotton seed hull baits. Grape and apple-grape baits attracted more larvae after one day in the field than they did on the first day while the number of larvae attracted to all other baits decreased after the first day. More sixth instar larvae were attracted overall, than either fourth or fifth instars.

Introduction

The bait filler of choice which is currently available commercially for control of black cutworms in the Midwest is apple-pomace bran (Sechriest and Sherrod 1977, Stockdale et al. 1976). During the heavy black cutworm outbreak of the 1977 growing season, apple-pomace bran with carbaryl bait was unavailable in many parts of Iowa (Stockdale 1977). The formulation of the bait was greatly reduced due to a fire which burned down a warehouse in Michigan during 1976 from which most of the apple-pomace for bait formulation in the Midwest has come.[4]

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[4]Personal communication with Harvey Ernst, Hopkins Agricultural Chemical Co., Madison, Wisconsin, August 1977.

If other materials were available for use as bait fillers, it is possible that the shortage of prepared bait for control of black cutworm outbreaks could be avoided. With this idea in mind, I took seven materials, screened in previous laboratory studies, and compared them in the field to see if they offered attractive alternatives to the currently used apple-pomace bran filler.

Another problem with black cutworm infestations is their lack of predictability. Archer and Musick (1977) have been concerned with developing methods for sampling and estimation of larval black cutworm population densities in corn. They used a 3-day sampling period and found apple-pomace bran baits more effective than pitfall traps for estimating population densities. Apple-pomace bran baits were considerably more attractive to larvae than were 2 other baits tested, alfalfa pellets and cornmeal-bran pellets. More importantly, the apple-pomace bran bait gave a consistent recovery rate indicating its potential as a cutworm population density indicator in corn.

Methods and Materials

Fourth, fifth and sixth instar larvae were used from a black cutworm colony maintained at the Corn Insects Research Laboratory, Ankeny, Iowa and reared according to a modification of Reese *et al.* (1972). To avoid excessive inbreeding and unnatural selection, the colony had been started fresh each year from field-collected black cutworm larvae.

On June 8, 1977, after standard field preparations, a long season field corn (B73 x Mo17) was planted in 30-inch rows, 8 inches between hills, in a 1.2 ha field on the Iowa State University Research Farm at Ankeny, Iowa. The late planting date was necessitated by naturally occurring infestations of black cutworms during April and May, which caused heavy damage and uneven stands in earlier planted corn on this farm. When the corn reached the 2-leaf stage, (Hanway 1971), preparations were made to place the baits in the field. The baits tested were: apple-pomace bran, bran, grape, apple-grape, citrus, cotton seed hulls, cornmeal and a control (field soil). All materials were pelletized except for cornmeal and the controls.

The baits were prepared by weighing out 20 g of each material and placing it in a 177.4 ml (6 oz) cardboard ice cream cup and sealing it with an externally labeled ice cream cup lid. The baits were taken to the field station and placed in the plots on June 23, 1977.

Each plot was six rows by 6.1 m (20 ft) and the plots were arranged so that six rows were left between plots and there were three plots fitted across the field, with 6.1 m between plots down the rows. All eight baits were present in each plot and were arranged in a completely randomized manner within each plot. The treatment factors were: 1. wet versus dry bait and 2. fourth, fifth and sixth instar larvae. Therefore, there were six treatment combinations per replication. The experiment was designed as a split-plot with four replications.

The baits were situated in the two center rows of each plot with four baits per row. The 6.1 m rows allowed for 1.2 m spacings between baits as well as 1.2 m of row on each end beyond the outermost baits. The cups were set in the middle of the row using a 15.24 cm Par-Aide golf cup hole cutter to make a hole just deep enough so that the lip of the cup was even with the soil surface. Dirt was hand packed around the cup lip, so that crawl spaces for larvae would not be readily available.

On the afternoon of June 23, 1977, a heavy thunderstorm hit the Ankeny farm with from 2.54 to 5 cm of rain. The field became muddy but there was enough slope to drain the water and the lids on all the baits remained watertight even though the following morning some cups had to be dug out of 2.54 to 5 cm of mud.

At 0500 on June 24, 1977, the larvae were released into the field. Each plot received 1 instar and 20 larvae were placed evenly along each row so that 180 larvae of a given instar were set in each plot. As soon as the larvae were released, the lids of the baits were removed and two 6-penny nails inserted into the outer edge of the lid. These nails were then inserted into the soil on either side of the cups until the lid was about 2.54 cm from the soil surface. This served to protect larvae drawn to the baits from birds, which according to Archer and Musick (1977), learn to feed on black cutworms at bait stations.

In plots which were to have wet baits, 10 ml of distilled water was poured into each cup with a 10 ml volumetric flask. All baits readily absorbed water and swelled considerably as the water was taken up. As a result of this, the cotton seed hull pellets swelled out of their cups. We resorted to using only 8 to 10 g of cotton seed hull pellets in the plots which had wet bait to keep the pellets from swelling over the sides of their cups.

The cups were checked for the number of larvae in them between 0700 and 0900 each day for three days after infestation. Black cutworm larvae in the fourth and later instars are relatively easy to see and we removed each larva from the cup in which it was found and placed it 2 rows away hoping to avoid a "learned" response to a given bait station, yet not depleting the population level in the artificially infested plot.

It should be noted that the control treatment consisted of a 177.4 ml ice cream cup containing 4 g of field soil. I wished to avoid a pit-fall trap approach, therefore, the control enabled me to determine whether the baited cups were acting as attractants or pitfalls. Similar to observations in the laboratory, the larvae had no trouble climbing up the sides of 177.4 ml ice cream cups.

An added advantage to the methods used here over those of Archer and Musick (1977) was that with the baits in the cups it was not necessary to spread the bait over the ground when counting the larvae. A problem with bait on the soil surface is that the pellet picks up moisture and falls apart, creating more surface area that possibly affects the attraction range of the bait. This method enabled me to probe through both the wet and dry bait in a confined area.

The recordings were taken daily for 3 days; the date of recording was analyzed as the split-split-plot effect of a split-split-plot design baits were the split-plot treatments, and the factors of replication, instar and wet or dry bait were the whole-plot treatments.

Results and Discussion

Table 12 shows that the effects of instar, bait, date and replication are significant.

Sixth instar larvae were trapped significantly more often (1.3 larvae/cup) than were fourth or fifth instar larvae (both were 1.0 larvae/cup). Significantly more larvae were trapped on the first two days than on the third day with a mean of 1.55 larvae/cup on the first day, 1.3 larvae/cup on the second day and 0.42 larvae/cup on the last day. I felt this was due to population dispersal and perhaps to a decreased level of attraction by the baits.

Significant differences occurred between replications (Tables 12 and 13). There were a number of possible reasons for this, including: 1. field slope, 2. directional movement of the infested larvae and 3. higher mortality of larvae in the first replication. Since the aberrant replication (no. 1) was located at the head of the slope and was also situated at one end of the field of plots, it is possible that these factors either singly or combined caused fewer larvae to be found in cups in it.

The larvae displayed very strong differences in terms of attractancy to the baits (Table 14). Grape, apple-grape and bran pellets attracted significantly more larvae than all other materials. Interestingly, cotton seed hull pellets, which had been very promising in laboratory studies were the poorest performing material in the field. The very small number of larvae which entered the control cups strongly supported the idea that the baits actively attracted larvae to them. If there had been similar numbers of larvae in control cups and baited cups then I would have felt the cups had acted merely as pitfalls but this is clearly not the case. The interaction between bait and date of recording (Table 15) showed that bran attracted a significantly large number of larvae on the first day. On the second day, both grape and apple-grape baits attracted significantly more larvae than all other materials. All materials deteriorated by the third day and there were no significant differences between baits and the control.

Overall, there were no significant differences between wet and dry baits. Sechriest and Sherrod (1977) stated that dry pellets in the field must absorb some moisture, either from the air or soil, before they will effectively attract black cutworm larvae. In our laboratory studies, wet baits were significantly more attractive than dry baits. I believe that the extremely wet conditions in the field when this experiment was started could have provided enough moisture to the "dry" baits to increase their attractancy. Also, the wet field probably increased larval activity and thus larval movement into the areas of effective attractancy of the baits increased larval visits.

Curiously, the interaction between wet or dry baits and the date was significant (Table 12). Figure 1 shows the steady decrease in response to dry baits and the increase in response to wet baits on the second day. By the third day responses to both wet and dry baits were minimal. While the field in which the plots were situated was quite wet on the first day, it had dried out on the surface by the second day under clear skies and high temperatures of about 32-33°C. It is possible that the high humidity and wet soil conditions helped to cause the similar larval recoveries between wet and dry baits on the first day. The wet baits were noticeably wetter on both the first and second days, but even they were dry on the third day.

Conclusions

Kelsheimer (1944) noted that the best performance of 3 poison baits (rice, bran, wheat bran and citrus pulp) occurred when the baits were freshly mixed and applied at twilight after which they were consumed by nocturnally active black cutworm larvae. These baits were not pelletized but were prepared by mixing bulk filler with appropriate insecticides and immediately applying the mixture. Herrick (1926) also stated that fresh bait was necessary in order to attract and kill black cutworm larvae. These baits had water and molasses added to make them moist and, perhaps, more attractive to the larvae. Both authors felt the baits lost their attraction as they dried.

Apple (1968) used pelletized baits against artificial infestations of black cutworms and noted decreased control as the baits aged. Our observations of 5 materials (bran, apple-pomace bran, citrus, cotton seed hulls and cornmeal) decreasing in attractiveness through time are in agreement with the literature. On the second day in the field, grape and apple-grape baits attracted more larvae than the other baits and more than they themselves did on the first day. Therefore, these two materials could significantly increase the effectiveness of baits for black cutworm control. Bran was also a high performing material, and has historically been used for baiting in black cutworm control but it decreased in attractiveness after the first day in the field. Apple-pomace bran performed considerably below the level of these three materials, however, it has been the primary material used for bait control of black cutworms.

Based on this study, pelletized grape, apple-grape and perhaps, bran show promise as baits for black cutworm larvae. Due to their greater attractancy than apple-pomace bran to black cutworm larvae, it is possible that these baits could increase the efficiency of monitoring populations of black cutworm larvae (Archer and Musick 1977).

Table 12. Analysis of variance for the number of black cutworm larvae collected in baits in the field using a split-plot design

Source of variation	Degrees of freedom	Mean square	F-value
Replication	3	13.62	9.660**
Instar	2	4.88	3.461*
Wet or dry bait (WD)	1	3.36	2.387
Bait	7	21.95	15.567**
Instar * WD	2	.66	.468
Instar * bait	14	1.76	1.248
WD * bait	7	1.75	1.241
Instar * WD * bait	14	1.01	.716
Error a	141	1.41	
Date	2	67.67	52.457**
Date * instar	4	1.02	.791
Date * WD	2	6.11	4.736**
Date * bait	14	4.90	3.798**
Date * instar * WD	4	1.40	1.085
Date * instar * bait	28	1.59	1.233
Date * WD * bait	14	1.33	1.031
Error b	316	1.29	
Total	575	2.01	

*Significant at the 0.05 level.
**Significant at the 0.01 level.

Table 13. Mean number of black cutworm larvae per replication attracted to bait in the field

Replication	n	No. larvae/cup[a]
1	144	.64 a
2	144	1.14 b
3	144	1.29 b
4	144	1.29 b

[a]Means not followed by the same letter are significantly different at the 0.05 level using Duncan's multiple range test.

Table 14. Mean number of black cutworm larvae attracted to bait in a cornfield

Bait	n	No. larvae/cup[a]
Grape pellets	72	1.75 a
Apple-grape pellets	72	1.61 a
Bran pellets	72	1.61 a
Apple-pomace bran pellets	72	1.17 b
Citrus pellets	72	.86 c
Cornmeal	72	.81 c
Cotton seed hull pellets	72	.72 c
Control	72	.15 d

[a]Means not followed by the same letter are significantly different at the 0.05 level using Duncan's multiple range test.

Table 15. Mean number, per date, of black cutworm larvae attracted to different baits in a cornfield

Mean no. larvae/bait cup[a]					
6-25-77		6-26-77		6-27-77	
Bran	2.83 a	Apple-grape	2.54 a	Grape	0.87 a
Grape	1.88 b	Grape	2.50 a	Apple-pom-brn	0.63 a
Apple-grape	1.71 b	Bran	1.50 b	Apple-grape	0.58 a
Apple-pom-brn	1.63 b	Apple-pom-brn	1.29 bc	Bran	0.50 a
Citrus	1.58 b	Cornmeal	0.92 bc	Cornmeal	0.25 a
Cornmeal	1.25 b	Citrus	0.79 bc	Cottonseed	0.25 a
Control	0.29 c	Control	0.13 c	Control	0.04 a

[a]Means not followed by the same letter are significantly different, within columns only, at the 0.05 level using a Duncan's multiple range test.

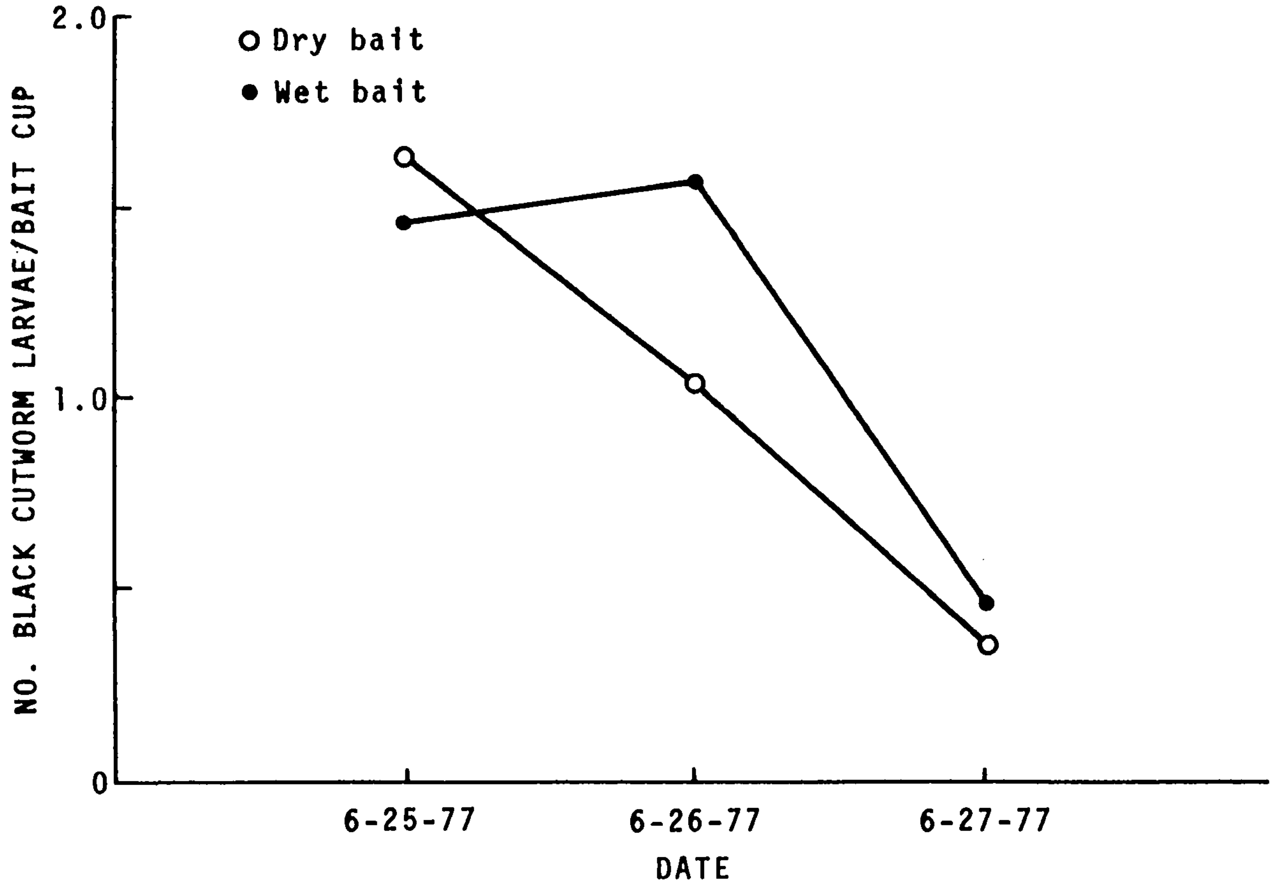

Figure 1. Wet and dry bait interaction curves for the mean numbers of black cutworm larvae recovered per bait station for 3 days in a cornfield.

PART III. GREENHOUSE STUDIES ON BLACK CUTWORM FEEDING BEHAVIOR IN SEEDLING CORN AND ORGANIC BAITS UNDER LIGHT AND DARK CONDITIONS

Abstract

Under greenhouse conditions, late instar black cutworm larvae cut significantly more seedling corn plants and fed upon more baits under dark conditions than in light. The feeding behavior followed closely the daily solar cycle except when the larvae were kept under dark conditions for 24 hours. In the absence of baits, fifth instar larvae fed significantly more often on corn seedlings than either fourth or sixth instars. However, when baits were present, the fifth instars fed less on both corn seedlings and baits than did the fourth, and significantly less than sixth instar larvae. In the absence of baits, fifth and sixth instar larvae cut over twice as many plants than when the baits were present. Strongly significant differences occurred in terms of the number of larvae recorded feeding in the different baits with apple-grape, grape and bran pellets the most attractive of all the materials tested. Overall, wet bait was preferred to dry but there were no significant differences between wet soil and dry soil.

Introduction

The black cutworm has often been alluded to as being a nocturnal feeder (Beirne 1971, Bethune 1908, Chamberlin and Madden 1942, Maxwell-Lefroy and Ghosh 1907, Purohit *et al*. 1971, Symons 1905). These general observations are in agreement throughout the literature but little work has been done to determine the extent and causes of nocturnal feeding. Nasr et al. (1973) concluded that black cutworm larvae were most active between 2000 and 0500 and that high temperatures and low relative humidities caused cessation of activity. Large percentages of larvae were observed active, but not feeding, under diurnal conditions. The authors speculated that larvae observed burrowing were escaping the heat or the direct sunlight.

Archer and Musick (1976) showed conclusively that late-instar black cutworm larvae were photonegative but hunger and the presence of food could overcome this taxis. Early-instar larvae were photopositive.

This study was designed to quantify the activity of late-instar black cutworm larvae through a 24 h period to determine if there were significantly preferred feeding times.

Organic baits and corn seedlings were used in this experiment to monitor larval activity and to gain some understanding of the effects of bait upon plant feeding. The final goal was to determine bait preferences, under wet and dry conditions, to fourth, fifth, and sixth instar larvae.

Methods and Materials

Larvae for this experiment were reared according to a modification of Reese et al. (1972), and no attempt was made to starve the larvae or alter the rearing photoperiod of light (14 h) and dark (10 h).

These experiments were run in a greenhouse at Iowa State University, Ames, Iowa, during October and early November, 1977. Solar radiation was relied upon for diurnal illumination but at night a variety of adjacent greenhouse lights and street lights altered the nighttime light intensity. To overcome this, I constructed a tent of 10 mil black plastic. This material came in rolls 3.75 x 30.48 m from which appropriate sized sheets were cut and fitted to completely surround 2 benches. When in place, the tent was 3.35 m in height, 9.14 m in length and 6.1 m in width and effectively omitted incidental light creating, as close as possible, nocturnal conditions similar to a moonless night in the field. The tent was set in place one-half hour after sunset and pulled back one-half hour before dawn. For the 24 h darkness studies, the tent was left in place continuously.

The experimental units were 35.6 x 50.8 x 15.2 cm soil flats, which were filled 11 cm deep with a 6 part soil, 1 part sand mixture and planted with 6 corn seeds in each of two rows, evenly spaced along the length of the flat. Since benches adjacent to the greenhouse walls were subject to more severe temperature changes, only the middle two benches were used.

In the first experiment, 7 baits were compared with a control for attraction to the larvae: apple-pomace bran, bran, grape, apple-grape, cotton seed hulls, citrus and cornmeal. Cornmeal was the only material not pelletized and the control cups were empty. The baits were weighed out in the lab and ca. 7.5 g of each placed in 29.6 ml (1 oz) clear plastic medicine cups. One cup of each bait and 1 empty control cup were then placed, in a completely randomized plan, in each flat with 4 cups between seedlings in each row. The cups were set into the flats using tablespoons and fingers, so the cup lips were level with the surface and no crawl spaces were available between the sides of the cups and the soil.

In half of the flats, ca. 2 ml of distilled water was applied via squeeze bottle to the bait and control cups while the rest were left dry. Each flat was infested with either 5 fourth, fifth or sixth instar larvae at 0700 h on the dates when the experiment was run.

In addition to the wet or dry bait and instar treatments, 3 trials were run with flats which had not been watered for 3 days and 3 trials were run where the flats were well watered the evening before infestation. The dry dates were October 7, 15 and November 5, 1977, and the wet dates were October 8, 14 and November 4, 1977.

Before infestation, vaseline was applied in a 2 cm band around the upper edge of the flats to discourage larval escapes. Five larvae of a given instar were placed equidistantly along the midline of the flat, between the two rows of corn plants and baits. One hour after infestation, the flats were checked for activity. Activity was gauged by larvae actually in the bait cups or feeding upon corn plants. These numbers were recorded hourly. Cutworms which were found in baits were removed from the flat, and replaced with untried larvae, one for one, so that an individual's preference for a given bait would not unduly weigh the comparisons between baits. Cutworms feeding on corn seedlings were not removed.

The design for this experiment was a split-split-plot with 4 replications on each date. Two replications were run on each bench. Since the runs on dates acted as a block effect, I treated dates as the whole plot effect of a split-split-plot. Wet or dry soil was analyzed as a part of the main effect since all flats were wet on 3 dates and all were dry on 3 other dates. The split-plot effects were baits, wet or dry bait, instars and replications. The split-split-plot effect was the hour of the readings.

Activity in baits was run in a separate analysis of variance from the feeding on the corn plant due to the different manner in which the larvae were handled when they were in the baits (i.e., removal).

A Duncan's multiple range test was run on the baits to determine which were significantly different.

The second experiment was set up the same as the first, except no baits were used, and wet and dry soil was included as a treatment on each date. Also, on November 19 and 25, the trials were run under 24 h of darkness while on November 18 and 26, the day/night cycle was as previously described. To create the 24-h dark cycle, the black plastic tent was merely left in place during the day as well as at night.

As in the first experiment, the larvae were monitored hourly, and the number of larvae feeding on corn plants and the number of cut corn plants were recorded. No larvae were replaced in this experiment.

Recording hygrothermographs were operating in the benches throughout both experiments. Since cutworm activity is greatly reduced at low temperatures (Satterthwait 1933), I attempted to keep the temperature around 21°C to 30.6°C, by adjusting the steam heat to thermometer readings. On clear, warm days, the temperature rose and relative humidity fell accordingly. There was no misting apparatus in the greenhouse and the only way to keep relative humidity up was to liberally sprinkle down the parts of the greenhouse not in use by the experiment. These crude methods led to a relative humidity variation of from 32% on clear dry days to 96% on rainy days. These conditions did give a fairly representative review of conditions likely to be encountered in the field.

Results and Discussion

In the first experiment, the whole plot effect of wet or dry soil did not cause significant variation for larvae feeding in baits or on corn plants (Tables 16 and 17). The overall means for this variable were 0.73 larva/bait and 0.89 larva/bait for dry and wet soil, respectively.

The numbers of fourth and fifth instar larvae found in baits were significantly different from the number of sixth instar larvae recovered. The numbers of larvae recorded averaged 0.68 larva/cup, 0.57 larva/cup and 1.2 larva/cup, respectively. There were no significant differences between instars for the number of larvae recorded as feeding on corn plants in this experiment (Table 17).

There were significantly different numbers of larvae recorded between the different baits (Table 18). The important information here is that the relationships between the baits in the greenhouse were similar to the field as shown in Part II. The only difference was that apple-pomace bran was significantly more attractive than citrus, cornmeal and cotton seed hulls in the field, but not in the greenhouse. Apple-grape, grape and bran baits were significantly more attractive to the larvae under both field and greenhouse conditions. The attractiveness of cotton seed hull pellets under laboratory conditions was in strong contrast with both field and greenhouse observations. Perhaps the cotton seed hull pellets had lost their attractive qualities by the time field and greenhouse studies were conducted. It is also possible that this material performed well when present by itself but could not compete with the other materials when in their presence. While relative humidity might affect the attractiveness of cotton seed hull pellets and other materials as well, it should be noted that cotton seed hull pellets performed uniformly well in the lab and uniformly poorly in both field and greenhouse trials under a wide range of relative humidities.

Wet baits attracted significantly more larvae than did dry baits (1.0/larva/cup and 0.6/larva/cup, respectively) (Table 16). This effect was inversely significant for the data on corn plant feeding (Table 17) where flats with dry baits had significantly more larvae feeding on the corn plants than did flats with wet baits. The interaction between the baits and whether the baits were wet or dry was significant (Table 16). Varying degrees of increased numbers of larvae were recorded in wet baits over dry baits, but the numbers retrieved from wet and dry controls were the same. There was a definite increase in bait attraction due to moisture.

The instar by bait interaction was significant and displayed interesting aspects (Table 19). All materials, including the controls attracted sixth instar black cutworms the most. Bran, apple-grape, and grape attracted significantly more larvae of all instars than all other baits. Bran attracted the most fourth instar black cutworms, grape the most fifth instar larvae and apple-grape the most sixth instar larvae.

Differences between the hourly numbers of larvae feeding in baits (Table 16) and the hourly numbers of larvae feeding on corn seedlings (Table 17) were highly significant. When the numbers of larvae in all baits were combined and compared against larvae feeding on corn (Figure 2), it was possible to show that a considerable amount of feeding occurred in baits and that larvae did not feed heavily on corn seedlings during daylight hours. A strong peak in bait feeding activity occurred mid-morning from 1000 to 1200 and lowest activity was at 1700, just before dusk. Feeding activity on baits and corn seedlings increased greatly with dusk and the ensuing nightfall. Bait feeding reached a peak at 2100 and tapered off through the remaining hours of night and morning. After 1800, feeding activity on corn seedlings was considerably greater than on baits, peaking at 2000 and 0100 with a sharp decline from 0500 to 0700.

Few larvae fed in apple-pomace bran, citrus, cotton seed hull pellets, cornmeal and the controls. Trends in feeding activity in these baits generally followed that of the total baits (Figure 2). The feeding activity trends for apple-pomace bran and controls (Figure 3) show a characteristic variation of considerable magnitude between hourly recordings that was common to cotton seed hulls, citrus and cornmeal. Black cutworm larvae displayed very prominent preferred feeding periods for bran, grape, apple-grape and corn seedlings. The great majority of larvae fed on corn seedlings and a distinct time-oriented activity preference was observed (Figure 2). There was little activity from time to infestation (0700) until 1700. Between 1700 and 1900, activity increased moderately so that about 1 to 2 larvae were feeding on corn plants in each flat. During all experiments, a strong surge of activity occurred beyond 1900 (after sunset) and lasted until 0500 when the numbers of larvae feeding on corn plants greatly decreased. The optimal feeding times on corn seedlings for black cutworm larvae were from directly after sunset to 1 h before dawn.

Feeding activity surged briefly in bran baits at 1000 but this was very short-lived and tapered off to almost no feeding through the afternoon hours. At 2000, ca. 2 hours after sunset, larvae started to feed in bran and this lasted, with variation between hourly recordings, until 0500 or about 1 hour before dawn. At that time an average of only 7 larvae out of 24 flats were feeding in bran (Figure 4).

Larvae fed in grape baits at a fairly steady rate from 0800 until 1500 with a peak occurring around 1200. Small numbers fed through the remaining afternoon and renewed activity started at 2000, peaked at 2100 and tapered off sharply after 2300 (Figure 5).

Apple-grape baits attracted rather large numbers of larvae from 1000 to 1200. After 1200, the numbers feeding in apple-grape baits fell off sharply until 1700, when an activity peak occurred between 1900 and 2000. After 2000, the larvae continued feeding in apple-grape baits at a moderate rate until 0500 when feeding almost ceased in this material (Figure 6).

Fewer larvae fed in dry baits and they had much shorter peak feeding activity periods than did larvae feeding on wet baits (Figure 7). From 1200 to 1700, the activity in dry baits was much lower than in wet baits. Larvae feeding in wet and dry baits had similar activity peaks at 2100. However, dry baits fell off sharply after 2100 and remained at a much lower level of activity than did wet baits which did not decrease in activity until 0400. By 0700, only a small number of larvae were active in either wet or dry baits.

While significantly greater numbers of larvae fed on corn seedlings in flats with dry bait than in flats with wet bait, the general trends and durations of feeding activities were similar.

Both date by instar (soil) and date by hour (soil) interactions were significant (Table 16), but the reason was due to the magnitude of feeding activity on the different dates. The relationships between the attractiveness of the baits and the periods of peak feeding activity remained constant through different dates.

Overall, wet or dry soil did not significantly affect the feeding activity of larvae in baits or on corn plants (Tables 16 and 17).

The analysis of variance of black cutworm larval feeding activity under normal diurnal and nocturnal regimes and all dark regimes indicated very significant differences between all dark and normal conditions (Table 20). An overall average of 21.5 larval feeding incidences occurred per flat under all dark conditions in 24 h and 11.9 occurred under normal photoperiod regimes.

Very significant differences occurred between the amount of feeding by instars in this experiment (Table 20). Fifth instars fed the most often with an average feeding incidence of 22.0/flat. Fourth instars were recorded feeding least often, 9.6/flat, and sixth instars were recorded at 18.3/flat. Regardless of the numbers recorded feeding, sixth instar larvae actually cut more plants than either fourth or fifth instar larvae (Figure 8 without baits).

There were highly significant differences between hourly readings and among the interactions, instar by hour and light/dark by hour (Table 20). The feeding activity differences between all dark and normal photoperiod regimes was very pronounced (Figure 9). The activity of larvae under normal photo period regimes followed the same pattern as in the bait experiments except the number of larvae feeding on corn seedlings was considerably higher in the bait experiments (Figures 2 and 9). I attribute this to the continual replacement of larvae which fed in baits. Newly introduced larvae tended to be very active for a period of time and I believe this caused the higher amount of activity on seedling corn in the bait experiments.

Feeding activity under all dark conditions increased from time of infestation (0600-0700) until 1900. After 1900, there was a major decrease in activity which ceased after 2100 but a prolonged peak lasted from 2200 until 0100, after which feeding fell off sharply and the differences between normal photo period and all dark regimes were minimal. This indicated that by keeping the test benches in the dark, activity was greatly increased through the diurnal periods. However, a distinct cycle was present in the feeding activity of the larvae and when feeding fell off in the early morning hours, starting at 0100, there was little, if any, difference between the two treatments.

Fourth instar larvae were observed feeding considerably less often than either fifth or sixth instar larvae (Figure 10). Few fourth instars fed from time of infestation until 1700 when their feeding activities started to increase and eventually peaked at 2400. Activity decreased until after 0300 when another peak occurred from 0400 to after 0500 after which activity decreased rapidly. While all three instars had an early peak at 1900, the main peak for fourth instars occurred 2 h later (2400) than the other two instars (2200).

Fifth instar larvae were the most active feeders and maintained a high level of activity from 1800 to 0200. Sixth instar larvae were not highly active in the morning but did surge to a moderate peak of activity at 1400 after which activity receded until 1700 when activity again increased. High levels of activity were maintained from 1900 until 0100.

Data were recorded during both experiments concerning the number of cut plants which occurred in each flat. When comparing the trials run under normal photoperiod responses of both sets of experiments, major differences in damage levels were recorded. These data were not statistically analyzed due to the different experimental conditions under which they were run. The number of plants cut by fourth instar larvae was not apparently affected by the presence or absence of baits. However, fifth and sixth instar larvae cut about 3 times as many plants when no baits were present than when baits were in the flats (Figure 8). Under these conditions, even though these baits had no toxicant in them and were not broadcast in the flats, enough feeding occurred in them to reduce the cutting of corn plants.

Conclusions

Within the limits described in this experiment, wet or dry soil conditions did not significantly affect the feeding behavior of the black cutworm. However, wet baits attracted more larvae and caused less corn seedling feeding than did dry baits. I agree with Sechriest and Sherrod (1977) that it is likely that when baits placed in a field become wet, either through predisposition of the soil or by subsequent precipitation, would be more attractive to black cutworm larvae than baits which remained dry. This is further supported by the fact that significantly more larvae fed on corn seedlings in flats with dry baits than those with wet baits.

In terms of overall attractancy to black cutworm larvae, apple-grape, grape and bran were highly superior to all other materials tested including the currently used apple-pomace bran bait. Black cutworm larvae display distinct feeding activity curves through 24 h periods. Feeding on corn seedlings was mostly limited to evening and nighttime hours. However, considerable feeding occurred in bran, apple-grape and grape baits during the late morning-hours and through noon. Since apple-pomace bran did not incur this behavior, any of these three baits would be able to further improve control of black cutworms, under diurnal conditions. It is theoretically possible that black cutworm control would be greatly enhanced if one of the top performing materials could be used as the filler for toxicant bait control.

The experiment which dealt with feeding behaviour under 24 h dark and normal, day/night conditions showed that daylight greatly decreased the amount of feeding activity. Except towards dawn, larvae, particularly fifth and sixth instars, fed upon corn seedlings at a high rate throughout the 24-h dark period. There was indication of a periodic feeding response as feeding almost ceased at 0500 or about 1 h before dawn.

Nasr et al. (1973) felt that nocturnal activity in this species was due largely to extreme temperature highs and relative humidity lows. While extreme high temperatures and low relative humidities during the diurnal period might encourage nocturnal activity, sunlight caused a distinct photonegative response resulting in decreased surface feeding activity. These results indicate that a negative phototaxis is the primary factor responsible for the nocturnal feeding behaviour of the black cutworm.

Table 16. Analysis of variance of the greenhouse study for the number of black cutworm larvae feeding in different baits for 24 hours

Source of variation	Degrees of freedom	Mean square	F-value
Soil[a]	1	.313	0.596
Error a	4	.523	
Rep (soil date)	18	.059	1.500
Bait	7	1.077	27.000**
Instar	2	1.699	42.475**
Wet dry[b]	1	1.831	45.750**
Bait * instar	14	.103	2.500**
Bait * wet dry	7	.171	4.250**
Soil * instar	2	.198	4.950**
Soil * wet dry * instar * bait	14	.079	1.975*
Date * instar (soil)	8	.110	4.998**
Date & bait (soil)	28	.075	1.050
Error b	846	.042	
Hour	23	.169	5.275**
Soil * hour	23	.090	2.828**
Date * hour	92	.128	4.003**
Wet dry * hour	23	.042	1.316
Instar * hour	46	.043	1.335
Bait * hour	161	.054	1.676
Error c	26801	.032	
Total error	27647	953.785	

[a]Wet or dry condition.

[b]Bait condition, either wet or dry.

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Table 17. Analysis of variance of the greenhouse study for the number of black cutworm larvae feeding on corn seedlings for 24 hours

Source of variation	Degrees of freedom	Mean square	F-value
Soil[a]	1	.560	.038
Error a	4	14.596	
Rep (Date Soil)	18	2.511	1.372
Wet dry[b]	1	7.973	4.355*
Instar	2	1.675	.913
Soil * instar	2	4.558	2.492
Date * instar (soil)	8	10.334	5.645**
Error b	107	1.826	
Hour	23	8.168	30.259**
Soil * hour	23	.618	2.289**
Date * hour (soil)	92	.978	3.627**
Wet dry * hour	23	.690	2.554**
Instar * hour	46	.268	.993
Error c	3105	.266	
Total error	3455	.448	

[a]Wet or dry condition.

[b]Bait condition, wet or dry.

*Significant at the 0.05 level.

** Significant at the 0.01 level.

Table 18. Mean number of black cutworm larvae which fed in each bait cup in the greenhouse

Material	n	No. larvae/cup
Apple-grape	144	1.32 a[a]
Bran	144	1.28 a
Grape	144	1.24 a
Apple-pomace bran	144	0.69 b
Citrus	144	0.63 b
Cotton seed hulls	144	0.60 b
Cornmeal	144	0.49 b
Control	144	0.18 c

[a]Means not followed by the same letter are significantly different at the 0.05 level using Duncan's multiple range test.

Table 19. Mean number of fourth, fifth and sixth instar larvae feeding in bait cups under greenhouse conditions

Mean no. larvae/bait cup[a]					
4th instar		5th instar		6th instar	
Bran	1.46 a	Grape	1.10 a	Apple-grape	2.00 a
Apple-grape	1.00 b	Apple-grape	0.96 b	Grape	1.79 b
Grape	0.83 c	Bran	0.77 c	Bran	1.63 c
Apple-pom-brn	0.71 d	Citrus	0.50 d	Cotton seed	1.06 d
Cornmeal	0.50 e	Apple-pom-brn	0.40 de	Citrus	1.04 d
Cotton seed	0.44 ef	Cotton seed	0.31 e	Apple-pom-brn	0.98 d
Citrus	0.35 f	Cornmeal	0.31 e	Cornmeal	0.67 e
Control	0.13 g	Control	0.17 f	Control	0.25 f

[a]Numbers not followed by the same letter, within columns only, are significantly different at the 0.05 level of Duncan's multiple range test.

Table 20. Analysis of variance of the greenhouse study for the number of black cutworm larvae feeding on corn seedling under normal photoperiods and 24 hours of darkness

Source of variation	Degrees of freedom	Mean square	F-value
Light/dark[a]	1	92.240	28.650*
Error a	2	3.221	
Rep (date light/dark)	12	10.447	2.659**
Wet dry[b]	1	1.834	.466
Instar	2	54.048	13.753**
Light/dark * wet dry	1	4.605	1.170
Light/dark * instar	2	2.318	.590
Light/dark * wet dry * instar	2	1.480	.377
Error b	72	3.934	
Hour	23	8.625	16.922**
Wet dry * hour	23	.218	.431
Instar * hour	46	1.073	2.098**
Light/dark * hour	23	1.499	2.991**
Error c	2093	.505	
Total error	2303	.847	

[a]Normal, solar 24 hours photoperiod versus 24 hours darkness

[b]Condition of soil, wet or dry.

*Significant at the 0.05 level.

**Significant at the 0.01 level.

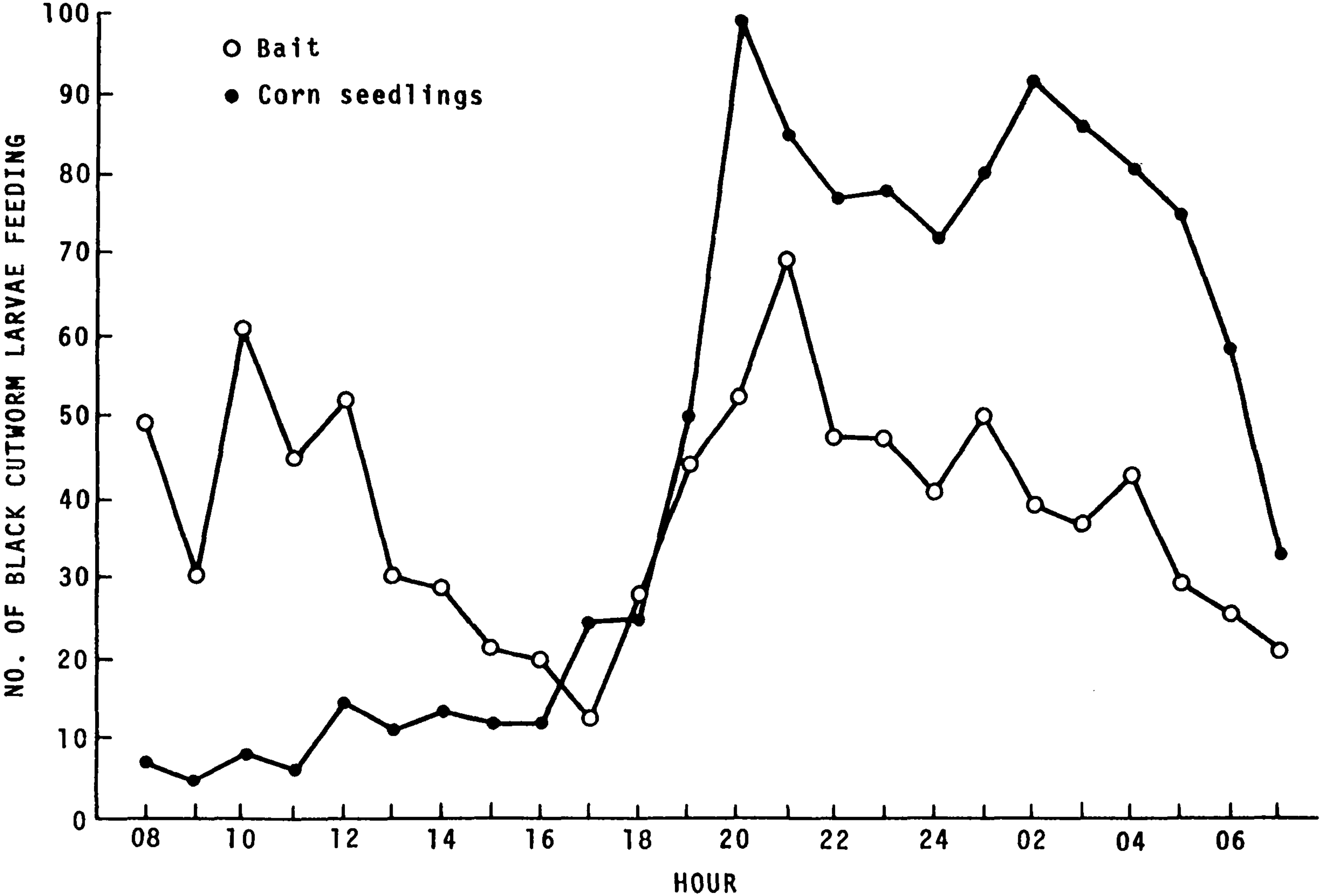

Figure 2. Hourly means of the number of black cutworm larvae feeding on corn seedlings and on all baits combined in the greenhouse.

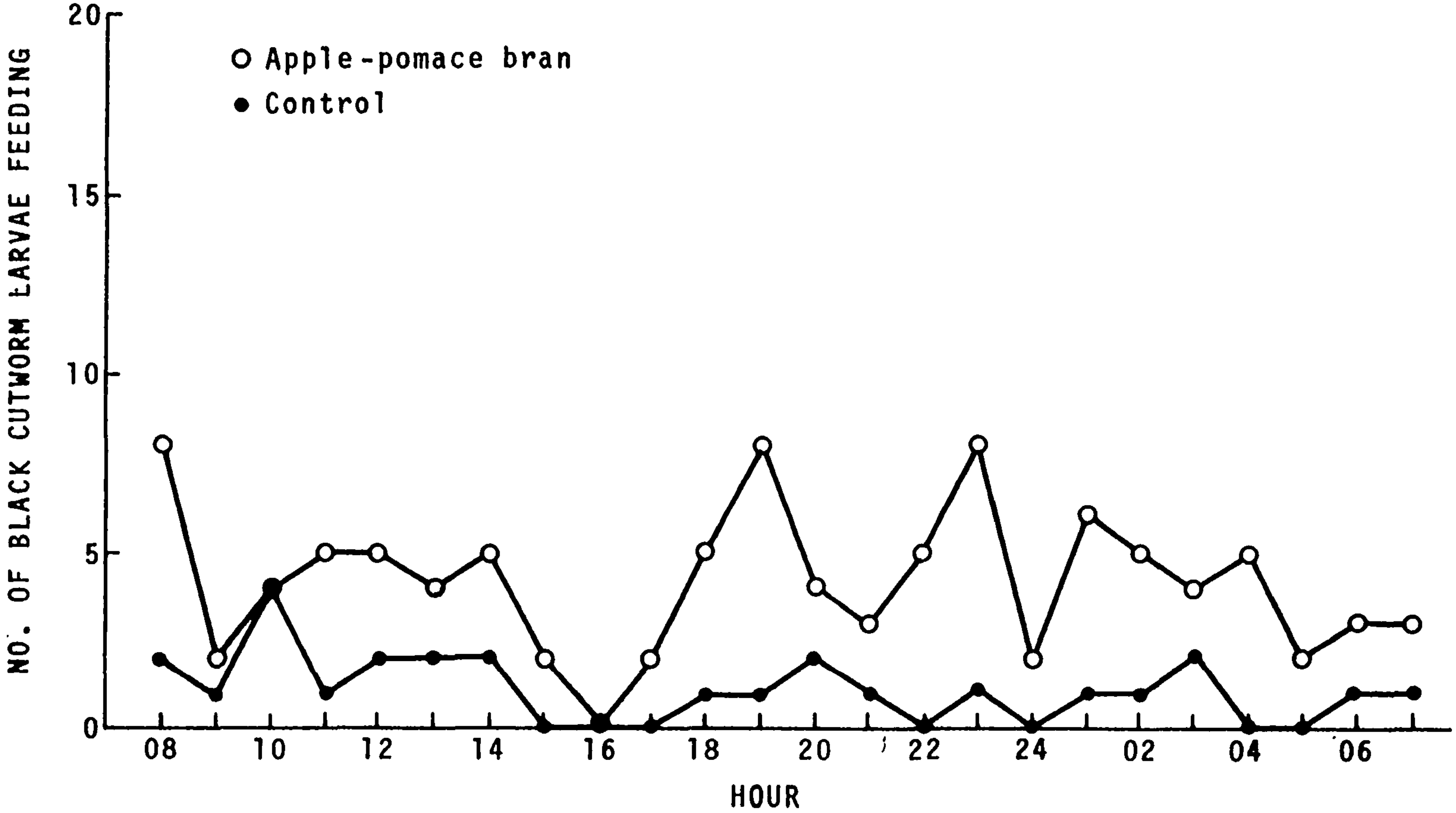

Figure 3. Hourly means of the number of black cutworm larvae recovered from apple-pomace bran baits and controls in the greenhouse.

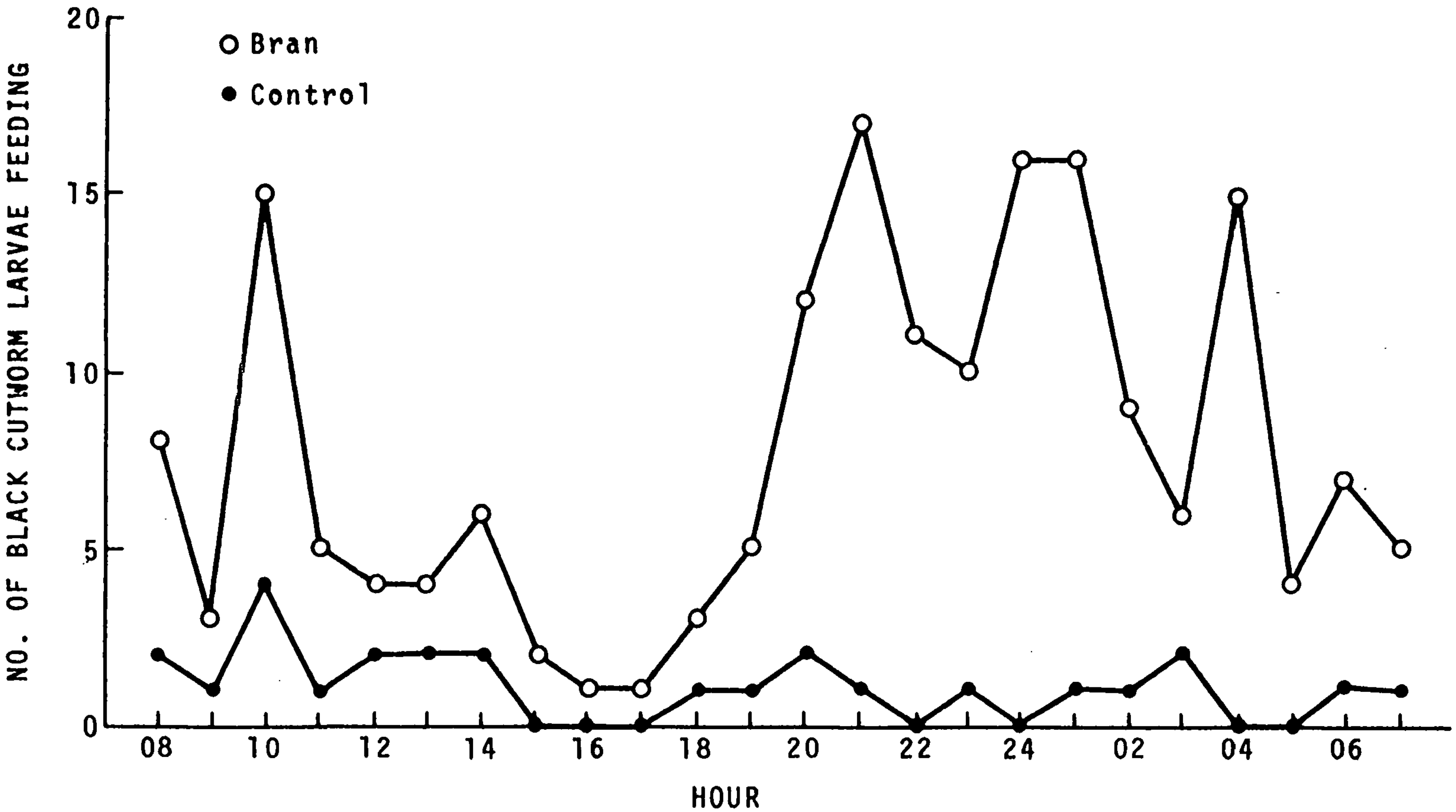

Figure 4. Hourly means of the number of black cutworm larvae recovered from bran baits and controls in the greenhouse.

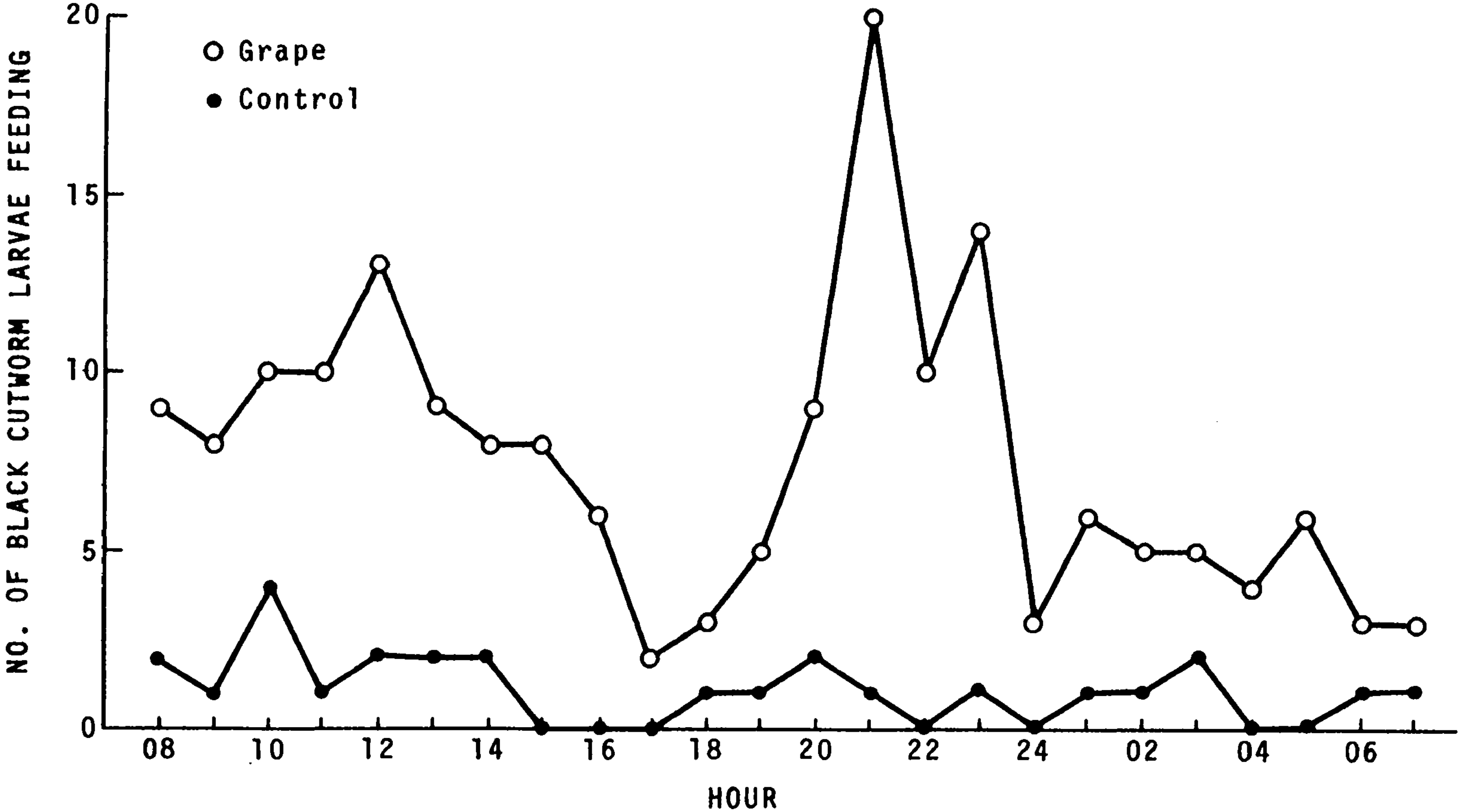

Figure 5. Hourly means of the number of black cutworm larvae recovered from grape baits and controls in the greenhouse.

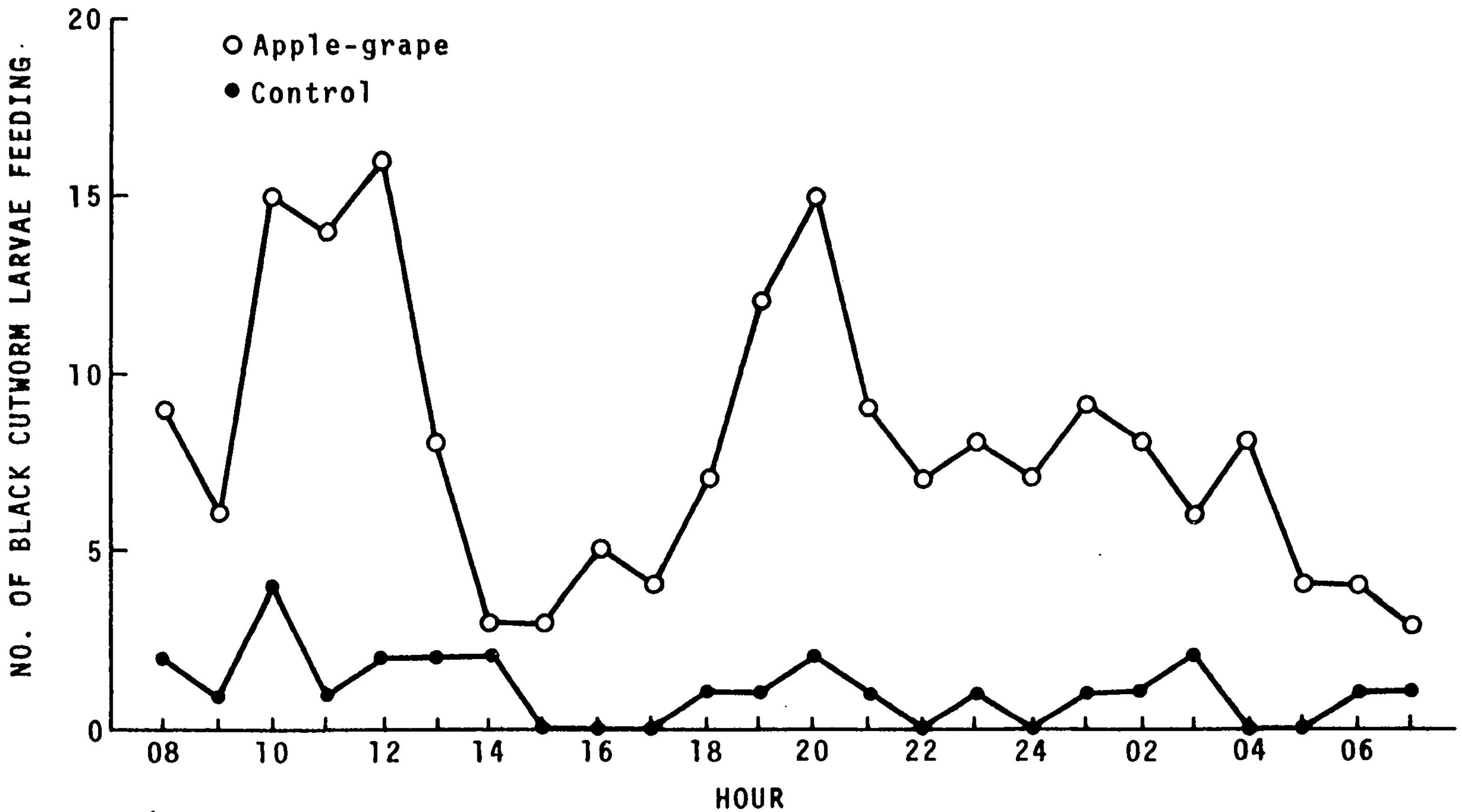

Figure 6. Hourly means of the number of black cutworm larvae recovered from apple-grape baits and controls in the greenhouse.

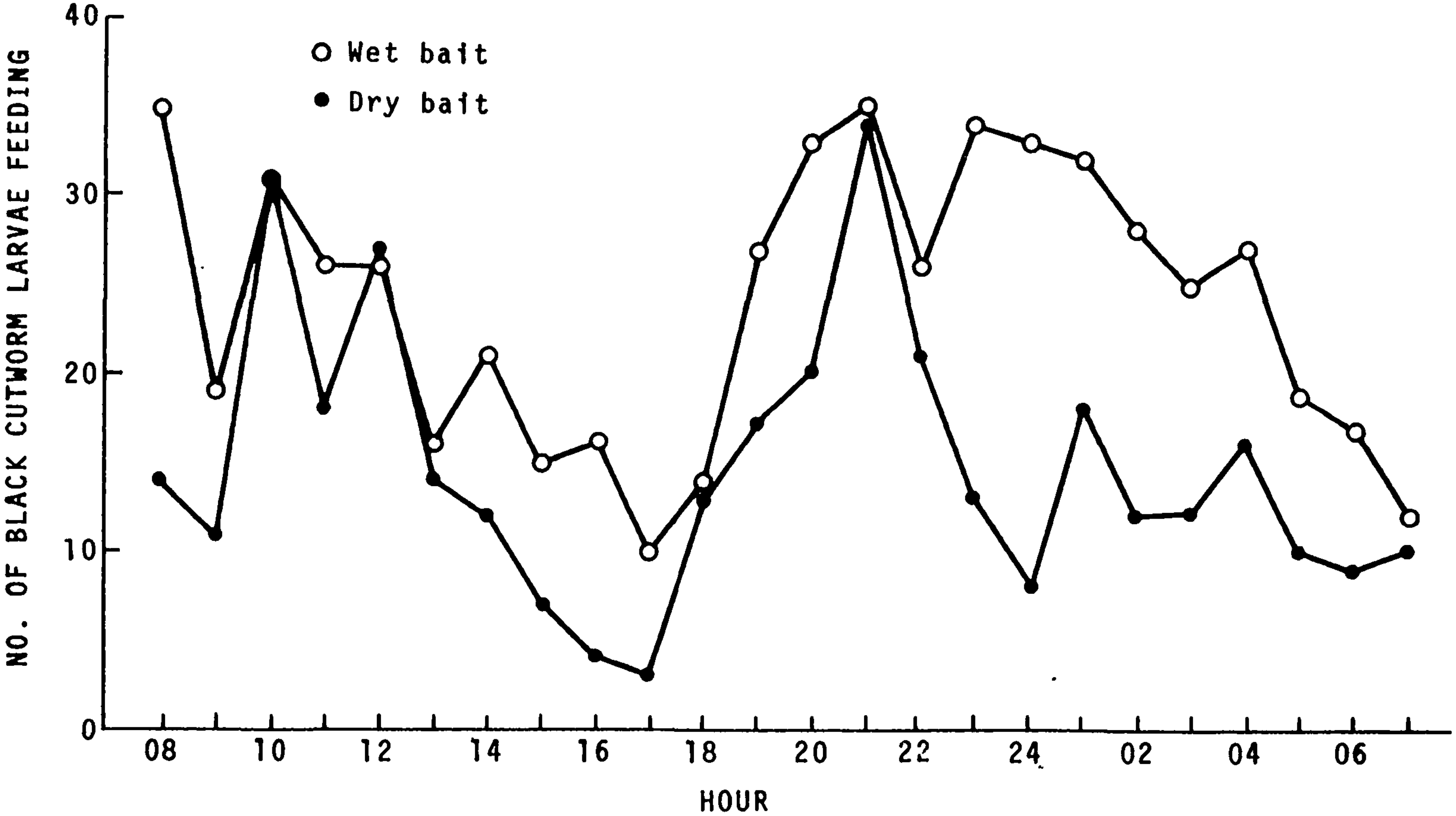

Figure 7. Hourly means of black cutworm larvae recovered from wet and dry baits in the greenhouse.

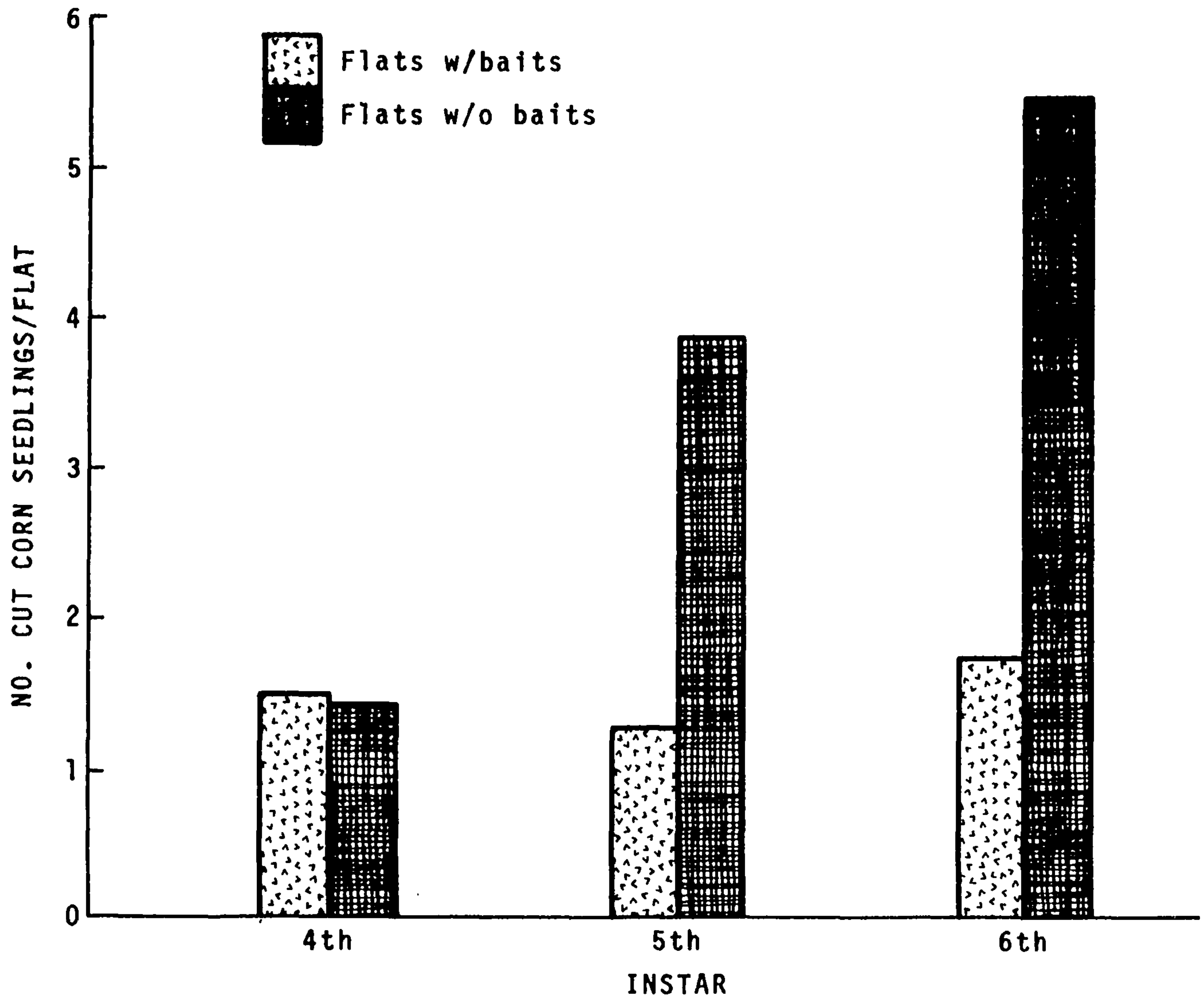

Figure 8. Means of the number of cut corn seedlings in flats with and without baits by fourth, fifth and sixth instar black cutworm larvae in the greenhouse.

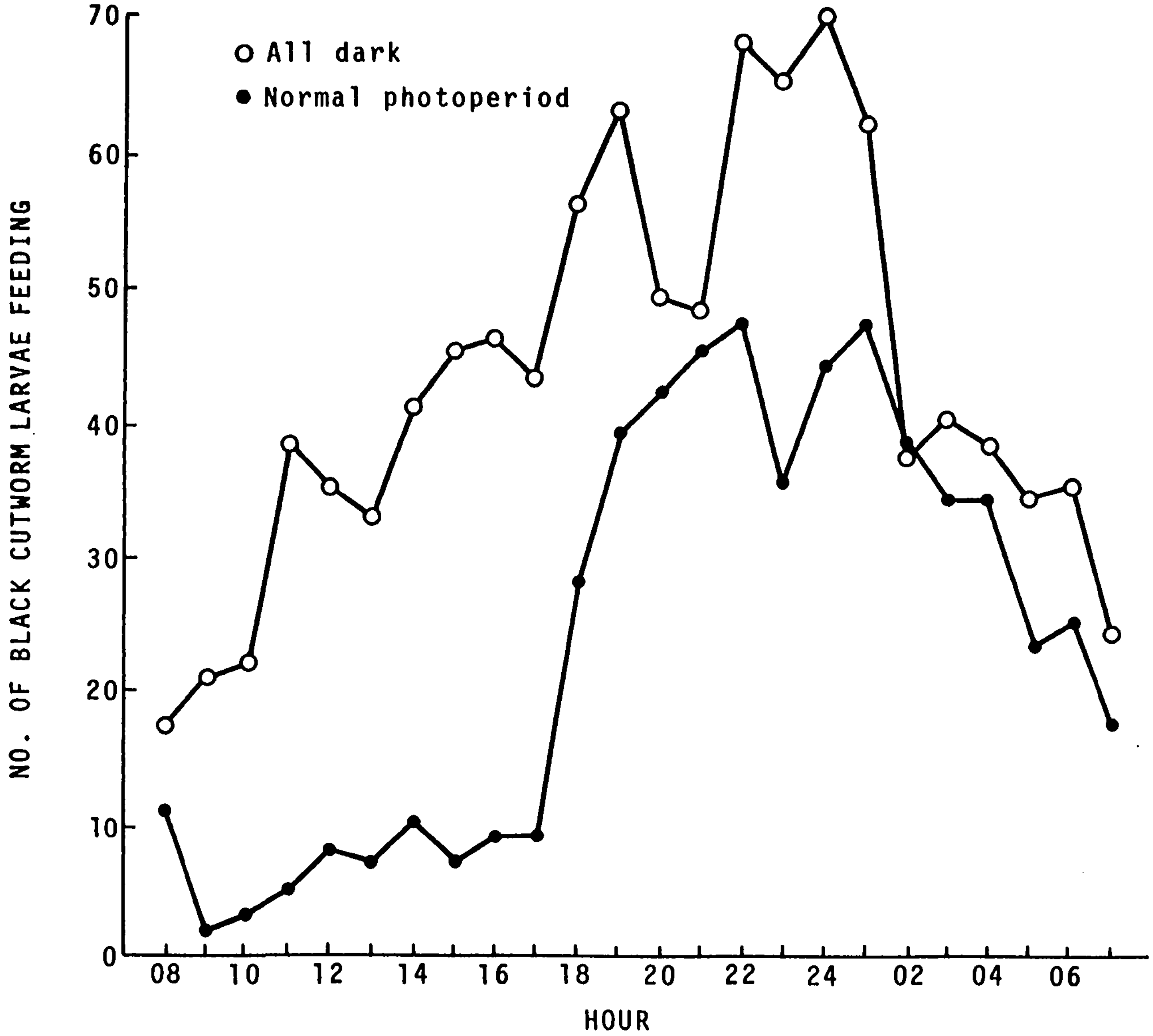

Figure 9. Hourly means of the number of black cutworm larvae feeding on corn seedlings under all dark and normal photoperiod conditions in the greenhouse.

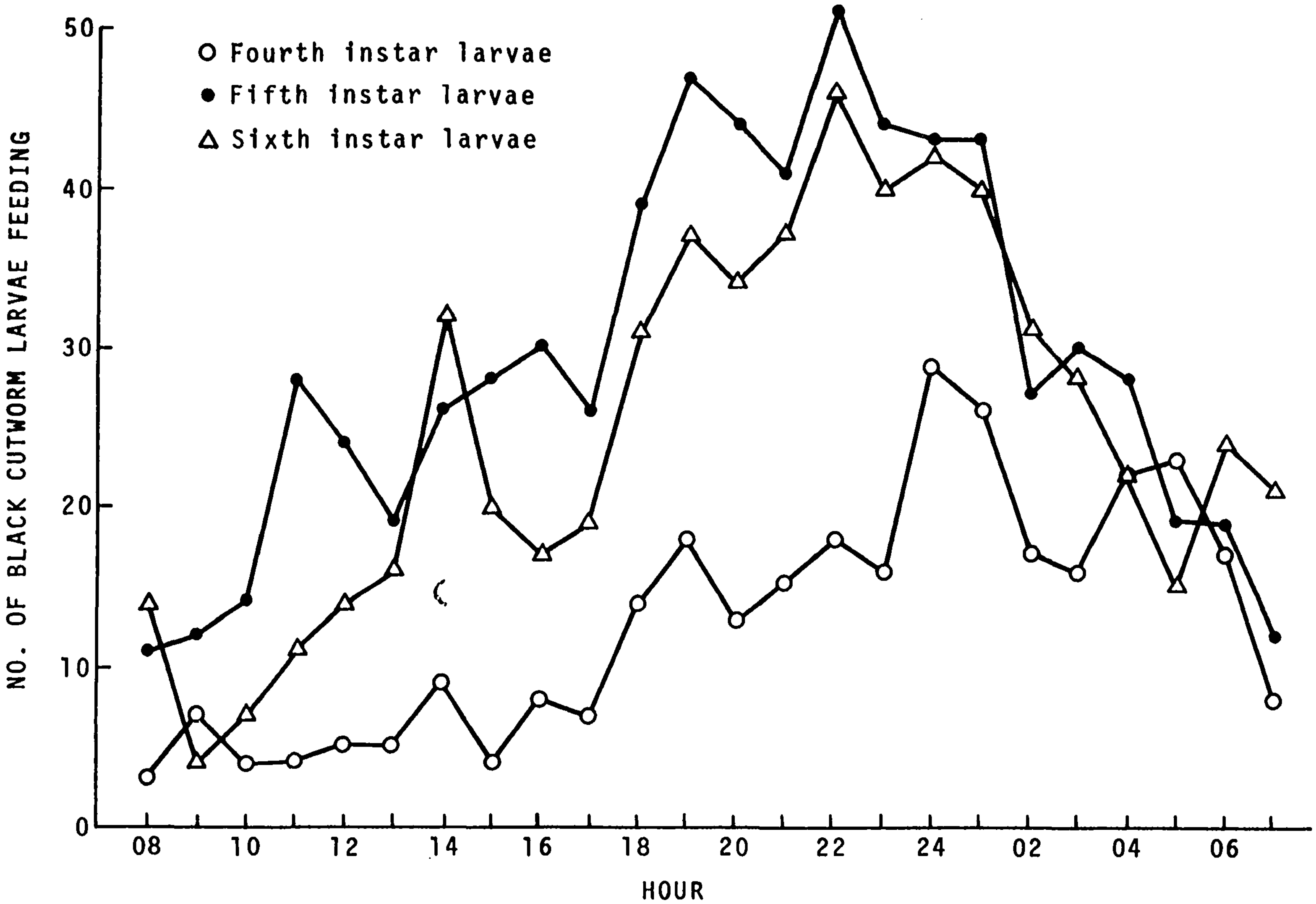

Figure 10. Hourly means of the number of fourth, fifth and sixth instar black cutworm larvae feeding on corn seedlings in the greenhouse.

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