Grasshopper Life Cycle

Grasshoppers in the Northern Plains have a one year life cycle with an active period that occurs, during most years, from early May to mid October. The grasshopper active period is exactly the same 5.5 month period of active grass growth of native upland sedges and native perennial cool and warm season grasses.

Most grasshopper species spend the 6.5 month inactive period through the winter as a partially developed embryo stage in an egg. Grasshoppers transition by simple metamorphosis through three life stages; egg, nymph, and adult. The majority of grasshoppers' life cycle is egg-nymph-adult-egg. A few grasshopper species spend the winter period as an hibernating mid to late stage nymph. Their life cycle is nymph-adult-egg-nymph.

Egg survival during the winter months depends upon the amount of standing vegetation and snow cover that insulates the soil temperatures from low air temperatures. Without insulation, long periods of subzero air temperatures can greatly reduce the soil temperatures decreasing embryo survival. Munro (1939) found high survival rates of *Melanoplus sanguinipes* eggs collected during early May in eastern North Dakota with an egg viability of 94%. However, when the soil was dried, the eggs did not survive.

Grasshopper egg hatch in the Northern Plains usually occurs from early May to late July. Eggs of grasshopper species tend to hatch during the same periods each year. In the Northern Plains, *Aeropedellus clavatus* is one of the first grasshoppers to hatch and *Phoetaliotes nebrascenis* is among the last grasshoppers to hatch, that overwinter as an egg (Hewitt and Onsager 1983, Watts et al. 1989). The grasshoppers that overwinter as a nymph usually hatch a month later than the late hatching grasshoppers. These seasonal hatch periods of grasshopper species have been categorized into five hatching groups. The **very early hatch** occurs from late April to early May; the **early hatch** occurs from mid to late May; the **intermediate hatch** occurs from early to mid June; the **late hatch** occurs from mid to late June; and the grasshoppers that overwinter in the nymph stage have a **very late hatch** that occurs from mid to late July. The actual time of hatch can vary from year to year. The hatch time mainly depends on the total amount of accumulated heat units received by the eggs. The quantity of heat units varies with the depth of egg deposition; eggs at shallow depths accumulate heat units more rapidly than eggs at deep depths (Cushing 1993, 1996; Pfadt 1994; Cushing et al. 1996).

The air temperatures of the preceding autumn effect the quantity of heat units accumulated by the egg pods prior to diapause. Soil temperature and soil moisture of the soil around the egg pods effects the winter survival of the eggs (Watts et al. 1989). The spring air temperatures effect the rate of heat unit accumulation, the rate of embryonic development, and thus the egg hatch date (Fisher et al. 1996a). The duration of egg hatch for most grasshopper species is around 4 weeks with a range of 2 to 6 weeks (Pfadt 1994).

Embryonic development begins immediately after egg deposition. The embryos receive nourishment from the yolk (Pfadt 1994). The rate of embryonic development depends on receiving sufficient heat units measured in day-degrees. Day-degrees (DD) are the accumulation of degrees each day that are above the threshold temperatures of 50° or 55° F (10° or 13° C). Grasshopper eggs require about 400 DD day-degrees of heat by fall in order for development to reach embryo stage 19, which is 50% developed. Most grasshopper species cease embryonic development at stage 19 (50%); some grasshopper species cease development at stage 24 (80%), and begin diapause (Pfadt 1994). At the onset of diapause, the growth hormones are shutdown, growth and metabolic activity cease, some physiological activity continues, and resistance to environmental extremes increases (Fisher et al. 1996a). Diapause is an evolutionary adaptation that functions to prevent completion of embryonic development and hatching of nymphs during the inclement weather of late fall or winter, when the nymphs would have a low chance for survival (Fisher et al. 1996a). Cold soil temperatures of winter end diapause and the embryos enter into a dormant state until spring warmup (Watts et al. 1989).

Eggs that do not receive sufficient day-degrees of heat between deposition and diapause, do not reach the necessary advanced embryonic development stage of the species and these embryos have reduced survivability and hatchability (Pfadt 1994).

During the next spring when soil temperatures reach the threshold temperatures of 50° or 55° F (10° or 13° C), the embryos resume their development (Fisher et al. 1996a). An additional 150 DD day-degrees of heat are required for the embryos to reach stage 27 (100%). A total of 500 to 600 DD day-degrees of heat are required for complete development from embryonic stage 1 to stage 27. About 400 DD of heat are required during the summer of egg deposition for embryonic development to stage 19 (50%) and about an additional 150 DD of heat are required the following spring to complete embryonic development to stage 27 and hatching (Pfadt 1994).

The rate at which the day-degrees of heat are accumulated determines the rate of embryonic development. Egg hatch is accelerated by moist soil and by temperatures above 50° F (10° C). Grassland canopy cover that has been reduced through low precipitation, heavy grazing, or mowing provides unobstructed access to the soil increasing the quantity of incident solar radiation resulting in elevated air and soil temperatures and an accelerated rate of accumulation of heat units causing increased rates of embryo development and earlier hatch dates. Egg hatch is delayed by dry soil and by temperatures below 50° F (10° C). Biologically managed moderately tall grassland canopy cover shade the soil surface reducing the quantity of incident solar radiation and lowering the grass canopy air and soil temperatures that cause slower accumulation of heat units and reduced rates of embryo development delaying the hatch date.

The embryos of a single egg pod hatch together within several minutes. The nymphs wiggle to the soil surface, still covered with an embryonic membrane, the serosa. The nymphs are unable to stand upright and they cannot jump away from predators until they squirm out of the serosa (Pfadt 1994). Newly hatched nymphs look like small adult grasshoppers except they lack wings, they have fewer antenna segments, and their genitalia are only rudimentary (Pfadt 1994).

The timing of egg hatch in the spring is important to grasshopper growth and development, and survival. Grasshoppers are cold blooded (old term: Poikilothermal; new term: Ectothermal). Grasshoppers are unable to regulate their body temperature metabolically. Their body temperature varies with the surrounding environment. In order to increase their body temperature above ambient temperature, grasshoppers absorb heat by basking in direct sunlight. In order to reduce their body temperature, grasshoppers elevate their body above the soil on the shady side of vegetation and hyperventilate to increase the volume of air moving in and out of their tracheae causing evaporative cooling (Carruthers et al. 1992). The evaporative cooling process would have physiological limitations to prevent desiccation.

The rate of nymphal development is determined by the nutritional quality of the food plants and by the amount of time the nymphs can raise their body temperatures to optimal levels through basking in unobstructed direct sunlight. The nymphs grow and develop; at intervals they molt (ecdysis) their old exoskeleton and change structure, form, and size. A diet high in crude protein is required to develop each new exoskeleton. The stage between molts is referred to as an instar. Most grasshopper species develop through five instar stages (Watts et al. 1989, Fisher et al. 1996a). The males of some grasshopper species develop through four instar stages. The females of a few large grasshopper species develop through six instar stages. Under typical environmental conditions, most grasshopper species develop from hatchling to adult stage in 30 to 50 days, at a rate of 7 to 10 days per instar. However, under cool, cloudy conditions, or if the grassland canopy cover shades the sun for long portions of the day, nymphal development rate is greatly extended. When the air temperature of the grassland microhabitat is below 65° to 68° F (18° to 20° C), the nymphs do not feed. If the period of low air temperatures is prolonged, nymphal mortality greatly increases (Campbell et al. 2006).

The grasshopper nymph becomes an adult, or imago, with the fifth or last instar molt. The new fledgling adult has fully functional wings, however, the reproductive organs are not fully developed. The young grasshoppers require a period of time, usually 1 to 3 weeks, to increase in weight and to complete maturation of reproductive organs (Pfadt 1994).

Grasshopper daily activities start shortly after dawn and are closely linked with the air and soil temperatures, wind speed, and light intensity. During the night, the grasshoppers body temperature is the same temperature as the environment (Parker 1982). The grasshopper crawls on the ground to an open spot that receives unobstructed direct radiant rays from the sun. The common basking position is to turn its side perpendicular to the sun rays and lower the associated hindleg, which exposes the abdomen. Periodically, they turn around and expose the opposite side and sometimes they expose their back (Carruthers et al. 1992).

Grasshoppers use incident solar radiation to raise their internal body temperatures above ambient levels. Grasshoppers can increase their body temperatures 25° to 28° F (14° to 16° C) above the air temperature, when they bask on open ground and are exposed to both the direct rays from the sun plus the rays reflected from the ground. Grasshoppers basking from a perch in vegetation can increase their body temperature only 15°to 18° F (8°to 10° C) above ambient temperature (Onsager 1998). The preferred optimal body temperature for rangeland grasshoppers is 95° to 104° F (35° to 40° C) (Parker 1982, Carruthers et al. 1992). Maintenance of body temperatures above ambient air temperatures requires the daily behavioral rhythm to be constantly connected with thermoregulation and all activity movements need to be related to solar position. Maintaining body temperature at high optimal levels increases metabolic rates, increases developmental rates, increases activity levels, and increases the speed of escape from predators (Joern et al. 1996). Maintaining body temperature at 104° F (40° C) can delay or reduce the impacts of infectious diseases from *Entomophaga* and *Nosema* (Carruthers et al. 1992).

The morning basking period usually lasts 1 to 2 hours on sunny days. Grasshopper daily activities begin after the air temperature has reached 81° F (27° C) (Jech 1996). Several rangeland grasshoppers feed on grass leaves from the ground. The grass leaves are severed from the plant, then consumed while sitting on the ground. Some grasshopper species feed by climbing onto the grass or forb plant with head up or head down and consume the leaves while still on the plant. Some grasshoppers climb onto the plant, cut off a leaf and let it drop to the ground, then climb down and consume the cut leaf while sitting on the ground. Feeding continues long enough to fill the grasshoppers crop and the feeding sessions stop until the crop is empty. While the crop empties, the grasshopper walks around aimlessly; this behavior is called pottering. The grasshoppers repeat the cycle of feeding sessions and pottering (Jech 1996).

Most grasshopper species are extremely discriminating when selecting food plants. The grasshopper approaches a potential food plant, lowers their antennae to the leaf surface and then drum or tap on the leaf with their maxillary and labial palpi. These sensory organs can separate the properties of plant chemicals into attractants or repellents. The grasshopper rejects the unfavorable plants and chooses the favorable host plants. If the first test has inconclusive results, the grasshopper may take a small bit to taste the leaf for an additional test (Pfadt 1994).

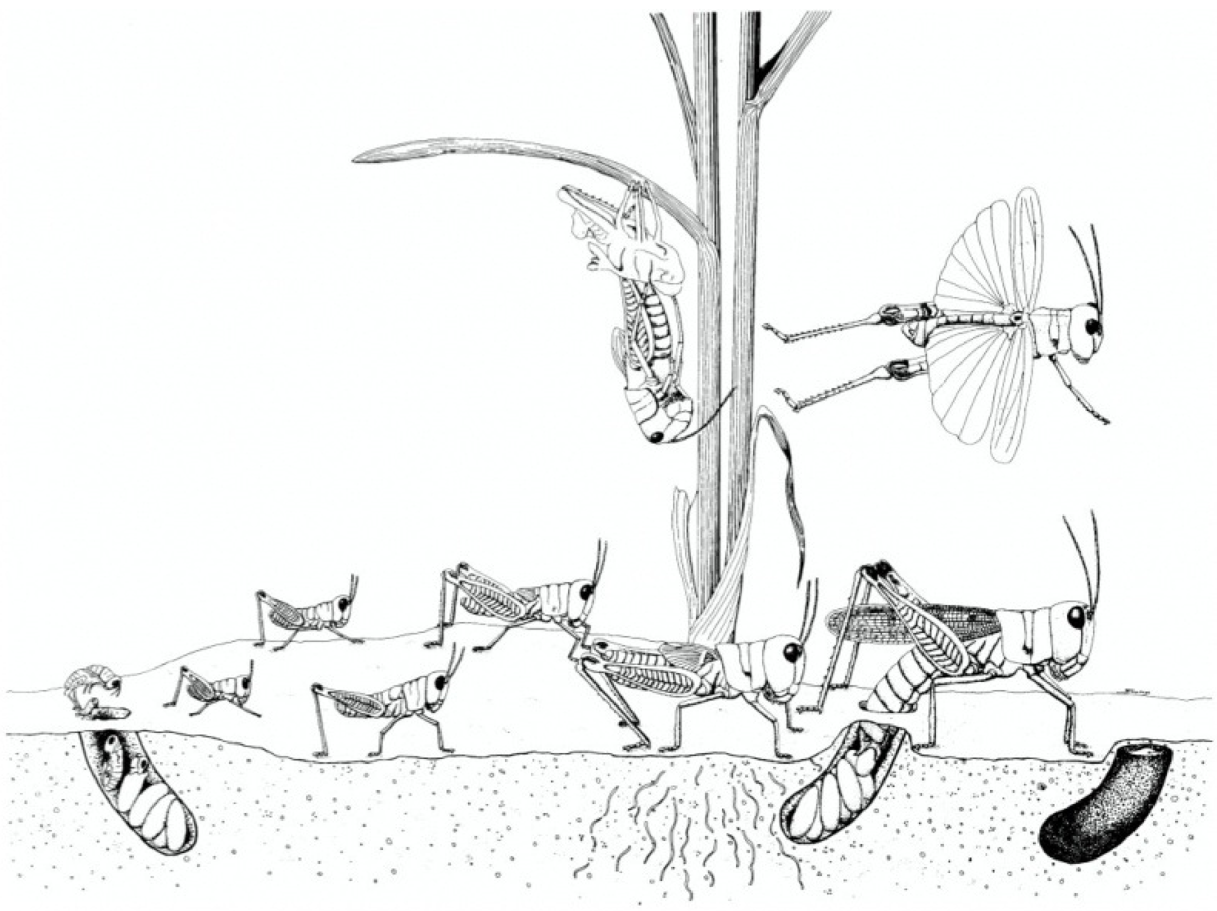
Grasshoppers remain active throughout the day as long as the air temperatures remain between 81° to 90 ° F (27° to 32° C) (Jech 1996). As the air temperature rises from 90° to 95° F (32° to 35°C), grasshoppers on the ground will stilt. They raise up on their legs to increase the distance between their body and the soil surface. With continued increases of the air and soil temperature, the stilting grasshoppers move stiff legged into the shade of vegetation. As soil temperatures approach 120° F (49° C), all other activities cease and the grasshoppers climb up grass stems or other vegetation, some species climb to a height of around 2 inches (5 cm), while other species climb to a height of 5 to 12 inches (13 to 30 cm) or even higher (Pfadt 1994). Grasshoppers perch on the shady side of the vegetation in a vertical position with the head up to avoid excessive heat. If the air temperature drops below 90° F (32° C) while there is still daylight, the grasshoppers will resume the cycle of active feeding and pottering. When the air temperature drops below 81° F (27° C), the evening basking period takes place until sundown. Daily activities are interrupted and the grasshoppers generally remain sheltered and inactive when air temperatures are below 68° F (20° C), the wind speed is greater than 15 mph (24 km/hr), the sky is overcast, or it is drizzling or raining (Jech 1996).

Female grasshoppers require a preoviposition period of one to two weeks between fledging and laying the first cluster of eggs in order to increase in weight and to fully develop their reproductive organs. The male grasshoppers usually hatch a little ahead of the females and are then fully mature when the females are completely developed (Pfadt 1994). Males actively search for mature females. The courtship varies with species. Grasshoppers are able to identify other members of its species. Grasshoppers communicate through visual and audible signals (Pfadt 1994). The bandwinged males court the females with short flights that flash their brightly colored wings and produce distinct crepitation sounds by snapping their wings (Gomez et al. 2012). The slantfaced males court the females with a species specific stridulation song that is produced by rapidly moving the hind femur, which has a row of small pegs on the inner surface, up and down against the tegmen, which is the leathery forewing (Davidowitz 2013). If she is enamored by his songs, they mate, otherwise, she ignores him or literally kicks him out. The male spurthroated grasshoppers do not produce distinct crepitation sounds or specific stridulation songs to count the females and little else is known about the courtship of melanopline (Pfadt 1994, Johnson 2002).

Following mating, the females require a period for egg development. The gravid female grasshopper deposits a clutch of eggs in a hole in the soil. The female may probe the soil several times to collect information on the physical and chemical properties of the soil. The selection of a favorable egg laying site is influenced by soil texture, temperature, moisture level, acidity, salt content, size of bare area, and type of vegetation (Pfadt 1994). Some grasshopper species select loose soil that is sandy or gravelly, however, most species select compact loamy soils. At a favorable site, the female digs a hole in the soil about 0.5 to 1.5 inches (1 to 4 cm) deep with her ovipositor. The female has three pairs of digging and egg laying structures at the end of the abdomen. The sides of the hole in the soil are lined with a secreted froth that becomes the egg pod (Davidowitz 2013). The clutch of eggs is deposited at the bottom of the pod. Many grasshopper species secrete a frothy glue between and surrounding the eggs, and some species do not. Additional froth is placed above the egg clutch at the top of the pod to act as a plug. Then the female places particles of soil on top of the plug with her hind legs (Fisher et al. 1996a). Each species has a uniquely shaped egg pod, and the number of eggs per clutch varies among species. A female grasshopper deposits a clutch of eggs about every 2 or 3 days. Most females are able to produce 4 to 25 egg pods with 1 to 90 eggs per clutch. The larger the clutch of eggs, the fewer the number of egg pods. The typical maximum number of eggs produced by one female is around 100 to 200 eggs. A few more fecund species, the *Melanoplus bivittatus* and *Melanoplus differentialis* are capable of producing 400 to 600 eggs per female (Pfadt 1994).

Embryonic development begins immediately after egg deposition. The rate of development of the embryo depends on the rate of accumulation of heat units. Eggs deposited at shallow depths, just below the soil surface, accumulate greater day-degrees of heat more rapidly than the egg pods deposited at medium and deep depths. The embryo must develop to at least stage 19 (50%) before diapause stops growth (Pfadt 1994). Thus, the one year life cycle of egg-nymph-adult-egg continues.

A few grasshopper species, such as *Eritettix simplex*, spend the winter as a late instar nymph. The nymphs become active in early spring when the air temperature and incident solar radiation permits sufficient elevation of their body temperature. The adults fledge in late April or May. Females oviposit eggs in early summer. The eggs hatch and the nymphs emerge in June and July. The partially grown nymphs hibernate under vegetation litter in late September or October. The grasshopper species that overwinter as a nymph, are the first grasshoppers to feed on young developing grass tillers before they reach the three and a half new leaf stage (Watts et al. 1989).



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from Pfadt 1994