AN ABSTRACT OF THE THESIS OF

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Title: Effect of Early Exposure of Tansy Ragwort (Senecio jacobaea) on Future Grazing Preferences of Sheep

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Tansy ragwort (*Senecio jacobea*) is a widely distributed weed in the Pacific Northwest (U.S.A.) where it causes severe damage to the livestock industry. Sheep are highly resistant to toxic effects of ragwort, therefore, induction of ragwort preference in sheep was sought as a means to control this poisonous plant. The effect of two early exposure periods to tansy ragwort on future grazing preferences of five sheep genotypes was evaluated. Lambs were exposed at six months of age (ragwort fed fresh), and then at 15 months of age (ragwort fed as pellets). Four treatment groups were created; lambs exposed during both periods (T1), lambs exposed only during the first period (T2), lambs exposed only during the second period (T3), and lambs not exposed in either period (T4). Ragwort preferences were evaluated at 17 (Exp.1) and 19 (Exp.2) months of age through direct grazing observation, and through plant observation before and after grazing. Experimental animals grazed in paddocks naturally infested with the weed. Results showed no treatment effects on preferences for tansy ragwort. In Exp.1 consumption of the weed was so limited that comparisons were not possible between sheep genotypes nor between treatment groups. In Exp.2 an interaction ($p<.05$) among treatment groups was found for the grazing observations, but ragwort consumption was still very low. No genetic differences were seen in Exp.2. It was concluded that different combinations of previous exposure to ragwort as evaluated in this trial did not induce preferences for the weed in adulthood. It was speculated that induction of ragwort preferences was not accomplished because of maternal absence during the exposure periods and because exposure occurred when the lambs were too old.

EFFECT OF EARLY EXPOSURE OF TANSY RAGWORT (*Senecio jacobaea*) ON FUTURE GRAZING PREFERENCES OF SHEEP

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1. INTRODUCTION

Manipulation of grazing preferences in sheep can apparently be accomplished by exposing the animals at an early age to the plants for which the preference is desired. In general, there appear to be periods in the development of young animals during which later behavior may be permanently modified. Early experiences, occurring during these "critical periods", seem to enhance the acceptance of certain foods during adulthood (Galef, 1977).

The critical period for developing food preferences appears to occur during nursing (Geyer and Kare, 1981). The young animal receives information about the dam's diet either by direct observation of her grazing or through her milk. Thus, maternal presence seems to be strongly associated with the development of early food preferences (Lynch et al., 1983); however, the precise timing of the critical period is not known, and few studies have reported induction of feeding preferences by exposing the young after the nursing period.

Lambs exposed an at early age to tansy ragwort (*Senecio jacobaea*) could possibly develop preferences for this weed and, at a later age, seek it out in pastures containing other plants which are usually more attractive. Senecio is highly poisonous and normally rejected by most livestock species; however, sheep seem to be willing to consume it, tolerating a lethal dose 30 times higher than the lethal dose for cattle and horses (Cheeke, 1984). The weed is widely distributed in the western United States, and in Oregon alone causes losses estimated at $20 million per year due to ragwort contamination of pastures, seed crops, hay and silage (Morrie Craig, personal communication)

Breed differences have been suggested in the ability of sheep to metabolize plant toxins (Culvenor, 1978). Differences in genotypes could also influence the way lambs respond to the early exposure of foods and the development of grazing preferences.

There were two main objectives of this experiment. The first was to evaluate whether preferences for tansy ragwort could be induced in sheep by different combinations of two previous exposure periods to that plant. Both exposures were after weaning. The second objective was to determine if the response of sheep to different exposure periods was affected by their genotype. Lambs of five genotypes were used. Promptness and extent of ragwort consumption in an infested pasture were used to measure the success of the previous exposure in determining later grazing preferences and to estimate how efficiently sheep could control the weed.

2. LITERATURE REVIEW

2.1. MECHANISMS OF FOOD SELECTION

THE THEORY OF NUTRITIONAL WISDOM AND HOW ANIMALS SELECT THEIR FOOD

Animals show greater preference for some foods than others, but whether they do that on the basis of quality is controversial. Futhermore, the term "quality" is controversial in itself, since a feed that is highly nutritious for one species could be poor or even toxic for another.

Much research has been done on diet selection and its relationship with both food quality and avoidance of poisons. Zahorik and Houpt (1977) explained that according to the theory of "Nutritional Wisdom", animals select foods which optimize their nutritional well-being and reject foods which are poisonous or low in nutritional value. Curt Ritcher (1943) supported the concept of "specific hungers". He proposed that animals can recognize specific deficiency states and that they know whether they are deficient in protein, minerals, vitamins, etc. According to Richter, they can also innately recognize the presence of a needed nutrient in food and preferentially ingest those foods containing the required nutrient.

The existence of a specific hunger for sodium is generally accepted. Denton (1967) reported that sheep, goats, and cattle can distinguish among foods containing various amounts of sodium, and by selective consumption adjust their sodium intake.

Contradictory results for nutrients other than sodium have been reported. Rozin (1967), working with thiamine in rats, made the animals vitamin deficient by feeding diet A, and then gave a choice between diet A and diet B containing the vitamin. The animals ate diet B. However, preference for diet B over diet A occurred even when neither diet contained the required vitamin. Rozin concluded that the choice of the vitamin-rich diet did not involve any ability to detect specific nutrients, but simply represented the rejection of a food which was associated with illness produced by the vitamin deficiency. His findings suggest that "Nutritional Wisdom" was not innately present but rather was acquired through experience with foods and their consequences.

Coppock et al. (1974) demonstrated that when dairy cattle are given a choice between two forages, one adequate and the other deficient in protein, animals which showed an initial preference for the protein-deficient diet did not switch their preferences even after developing protein deficiencies. Other work by Coppock et al. (1976) demonstrated that lactating cows deficient in either calcium or phosphorous did not consume enough dicalcium carbonate supplement to cure their deficiency, even though other cows ate large amounts of the supplement regardless of whether or not they were deficient in either mineral.

Potential involvement of poisons in diet selection is another factor to consider when studying animal food preferences. According to Garcia et al. (1976), if an animal consumes a flavored food and subsequently becomes ill, that animal will avoid or drastically reduce consumption of that flavor upon later encounters. The strength of the resulting aversion is directly related to the intensity of the flavor and of the illness, and inversely related to the length of the interval between consumption of the flavor and the onset of the illness. Galef (1977) found that adults rats can, in some fashion, lead their offspring to feed solely on a safe diet when in an environment containing food known by the adults to have been poisoned, thereby allowing the young to avoid ingesting potentially noxious foods. Pups learn to eat the diet that the adults eat rather than to avoid the diet the adults avoid.

There are many ways by which animals can deal with poisons. Laycock (1978) suggests that some of the possible evolutionary adaptations of large herbivores to cope with poisonous plants include consumption of a generalized diet that reduces the probability of eating a toxic amount of any one species, ability to detect and avoid poisonous plants, and ability to detoxify plant poisons. Regarding generalized diets, Zahorik and Houpt (1977) suggested that "the evolutionary pressure to consume a varied diet may be a more effective mechanism than learned aversions for preventing poisoning by plants which cause no symptoms unless they are eaten in very large amounts".

The basis for recognition of nutrients and poisons in foods has been referred to as an interaction of innate (genetic) and learned (environmental) factors. Cushing (1944) reported that differences in food habits of various species of bird raptors are maintained much more through non-heritable factors passed on by the behavioral interactions between parents and offspring than through specific heritable factors. Cushing found that young raptors do not show an inherited ability to recognize living animals as prey but rather must be taught to do this. The work of Kuo (1967) suggests the same tendency: "No individual animal, especially among the higher vertebrates, is born with a genetically predetermined range of behavior patterns aside from the anatomical and functional limitations of certain specific organs". According to Kuo, there is no genetic basis in the central organization that determines the kind of food which the young birds and mammals will eat. "Animals eat what they eat not because of what they are born with but because of what they are fed with" (Kuo, 1967).

THE EFFECT OF EARLY EXPERIENCE ON LATER FOOD PREFERENCES

Learning appears to be the cornerstone of food preferences. Experience seems to have different consequences depending upon age, physical development, and environmental conditions. It has been found (Capreta, 1977) that a young animal may be influenced in what it eats by what its parents feed it, by what it observes other adult animals of its kind eating, and by its own trial and error experiences of pleasure and discomfort with specific foods.

The induction of eating preferences by early exposure has been found in many species, as shown in table 1.

Table 1. Species in which the induction of eating preferences by previous exposure or early experience has been observed.

SPECIES	SOURCE
Meerkat (Suricata suricatta)	Ewer, 1963.
Domestic chicken	Capreta, 1977.
Snapping turtle (Chelydra serpentina)	Burghart & Hess,1966.
Domestic cat	Chesler, 1969.
Carneaux pigeons	Neuringer et al.1974.
Raptor birds (several species)	Cushing, 1944.
Domestic dog (Smooth-haired chow dog)	Kuo, 1967.
Chinese Mynahs	Kuo, 1967.
Garter snakes	Fuchs et al. 1971.
Japanese macaques	Itani, 1958.
Moose (Alces alces)	Edwards, 1976.

The presence of parents and conspecifics appear to be determinants in development of food preferences. Galef

(1977) found that adult rats introduce young to a subset of potential food items. Then, for a limited time following exposure, the young exhibit a tendency to ingest those items experienced as a result of social interaction in preference to unfamiliar items. Galef concluded that rats can affect their pups' choice of diet in three ways: via mothers milk, via their physical presence, and via the deposition of residual chemical cues. Geyer and Kare (1981) suggested several sources of experience of appropriate food during early life (preweaning) such as accompanying parents on foraging trips where the young can observe parents obtaining and consuming food or having foods cached within the nest. In some species the young is born where food is abundant and hoarded items are present in the nest area (stored vegetables or hunted prey). Other young mammals obtain food from the mouth of adults who bring pieces of killed prey or regurgitate food. Olfactory cues in the mother's milk may reflect her diet or dietary information concerning the mother might also be present in her excreta or clinging to the fur.

The findings of food preferences in precocial species such as turtles and garter snakes is of particular relevance. Upon hatching, these species are completely independent of parental care or attention. The work of Hess (1964) suggests that in precocial species, besides the imprinting produce by parental and social interactions, there may be habitat and food imprinting. Thus, even if some animals have no opportunity to learn what to eat from their parents or other conspecifics, they could "imprint" upon their first foods and prefer them when exposed to alternatives later on.

2.2. THE EFFECT OF EARLY EXPERIENCE & LATER FOOD PREFERENCES IN SHEEP

The effect of early exposure of foods upon later intake preferences in ruminants have scarcely been studied (Hart, 1985; Arnold and Dudzinski, 1978). Hart (1985) pointed out that this is an area that might receive more attention in the livestock industry as we attempt to find less expensive foodstuffs, some of which may be highly nutritious but unpalatable to the animals. Since ruminants (or rather their bacteria) can digest cellulose, we could convert old newspapers into milk or beefsteaks. Such use of paper or crop residues requires a supplementation of nitrogen, usually supplied in the form of urea (Hart, 1985). Unfortunately, urea is very unpalatable, and even when combined with molasses there may be highly variable consumption of the mixture by sheep (Lobato et al., 1980).

There also appears to be a lack of suitable management procedures to overcome the variable consumption of new supplements given to sheep while grazing. In extensive grazing areas domestic herbivores are often moved from pastoral areas, where they grazed native vegetation, to farming areas, where they must graze highly improved pastures. Frequently, farmers report that moved sheep perform poorly on the improved pastures (Arnold and Maller, 1977).

MATERNAL PRESENCE AND AGE AT PREVIOUS EXPOSURE ON DIET SELECTION

Maternal presence during exposure to new foods has been found to enhance induction of later grazing preferences in sheep (Lobato et al., 1980; Lynch et al., 1983; Green et al., 1984; Keogh and Lynch, 1982).

Green et al. (1984) conducted a trial to determine the effect of early exposure to wheat upon later consumption of the grain. To evaluate the effect of maternal presence during exposure, they created three treatment groups: lambs exposed to wheat with their mothers, lambs exposed to wheat without their mothers, and a control group which was not exposed to wheat. Consumption was later determined in consecutive opportunities and it was found that lambs exposed with their mothers ate significantly more wheat ($P<.001$) in all consecutive testings than either lambs exposed without maternal presence or the control group. This result suggests that there may be an element of behavioral imitation involved: lambs direct close attention to the feeding activities of their mothers and may get visual and olfactory information about foods acceptable to the mother, even if they do not actually consume such materials. Green and his coworkers remarked that prompt acceptance of wheat by adult sheep as a consequence of being pre-exposed with their mothers may eliminate problems with shy feeders when sheep are being supplemented in drought situations. Prompt acceptance should also reduce the incidence of grain poisoning from excessive intake during supplementation, since most sheep will immediately begin eating and become adjusted to wheat during the first days of feeding when only an introductory ration is being fed (Green et al., 1984).

Lynch et al. (1983) on the other hand, conducted an experiment to determine whether early exposure with experienced mothers would induce higher wheat consumption at maturity than early exposure with inexperienced mothers. They also had a control group, which was not exposed to wheat. The experienced mothers had been fed wheat for the previous 6 months during a severe drought. They also evaluated the effect of different ages at exposure: 1, 1 and 2, 1 to 4, and 3 to 4 weeks post-partum. Results showed no significant difference in supplement acceptance between the groups exposed at different ages, but indicated that lambs exposed with experienced mothers ate significantly more (P<.05) than lambs exposed with inexperienced mothers. It appears that exposing young lambs to wheat with experienced mothers is a practical method of ensuring that sheep will eat the supplement later on. These results also indicate that, given maternal presence, lambs could be exposed as early as 4 days after birth and as late as 4 weeks post-partum. At the youngest age, the few grains that the lambs could have eaten were apparently enough to influence their subsequent feeding behavior.

Other evidence suggests that early exposure to food could affect later preferences even without maternal presence. Lobato et al., (1980) exposed lambs and their mothers during the pre-weaning period to molasses-urea blocks. Later consumption of this supplement was determined and compared with that of animals which were either previously exposed to hay or had no exposure to any supplement (control group). His results show that lambs which had been offered blocks before weaning responded with higher intake than the other two groups when they were offered the blocks later on. Since he observed nearly all ewes and lambs consuming some of the blocks during the exposure period, he postulated that lambs may have adapted to the blocks by imitating their mothers or other ewes or by taste acquisition via the dam's milk. When Lobato repeated the experiment using different animals in a different location, he unexpectedly found the same results despite the fact that none of the lambs nor their dams consumed any blocks during the pre-weaning period. Given that the role of the ewes in the learning process of these lambs was uncertain, he suggested that familiarity with the block by sight, and perhaps adaptation by smell, were the factors that contributed to the high intake of the blocks later on.

Regarding the effect of age of exposure, Keogh and Lynch (1982) evaluated the effect of lamb exposure to wheat at 1, 2, 3, 6, and 9 weeks of age. Exposure consisted of 1 hour per day for 5 days. Their results show no significant effect of any of the evaluated ages on preferences measured later on. They also evaluated the effect of total length of exposure ranging from 5 to 45 hours. As with age, length of exposure showed little effect on the quantity of wheat eaten at testing time.

On the other hand, Arnold and Maller (1977) evaluated the effect of length of previous exposure under different pasture conditions in Australia. Lambs were grazed from birth for 6, 9, 14, 26, or 38 months at four locations, and then brought to a single location were their grazing preferences were evaluated. Their results suggested that grazing preference of sheep are influenced by experience in the first 6 months of life or longer but that these differences cease after one year in a new environment. Lobato et al. (1980), referring to this particular point, mentioned that it has not been established whether the critical age of first exposure to supplements lies in the pre-weaning period. He found that older sheep, from approximately 9 months old and older, may be unreliable in their responses to subsequent exposures.

PERSISTANCE OF FOOD PREFERENCES: THE PERIOD BETWEEN EXPOSURE AND TESTING, AND DIFFERENCES BETWEEN SUBSEQUENT TESTINGS

Keogh and Lynch (1982) found no effect of the interval length between exposure and testing upon preferences shown at time of testing. Animal preferences are well defined and remembered for at least 9 weeks after the first exposure (Lobato et al., 1980).

Lynch et al. (1983), working with previous exposure to wheat, measured the amount of wheat eaten by lambs when the testing period was conducted 1, 4, 7, 8, and 9 weeks after the first exposure to the wheat. They found that the amount of wheat eaten was not influenced by the interval between exposure and testing. However, this trial did not provide information about periods longer than nine weeks between exposure and testing. "If the prompt acceptance of wheat persists throughout life, then there would be no need to reinforce the response by offering wheat at regular intervals" (Lynch et al., 1983). To further pursue this matter, Green et al. (1984) extended the period between exposure and testing to 6, 12, 24, and 34 months. Results revealed no differences in supplement intake among those periods, indicating that the effect of previous exposure to wheat could last for at least 34 months.

On the subject of subsequent testing, evidence suggests that there is an effect of cumulative experience that tends to reduce differences in intake originated by differences in early exposure. Arnold (1964) raised sheep in four different environments until weaning at ten weeks, and then measured grazing preferences in one of those environments at three consecutive opportunities. Evidently, initial differences in grazing selectivity decreased with the experience of the animals. By the third testing period all groups had enough grazing experience to graze in a familiar pasture without significant differences in selectivity, regardless of the environment in which they grew up. Arnold concluded that the ability of lambs to obtain maximum intake from a plant community is partially determined by their experience in that community.

Lobato et al. (1980) exposed lambs during the 14 week nursing period to molasses-urea blocks, and then tested for its consumption 6 and 17 months later. Comparisons were made with a control group of non-exposed animals and with animals supplemented with hay. They found that sheep which had been exposed to molasses-urea blocks ingested more of the blocks in the two subsequent periods than those exposed to hay or no supplement, and that there was an effect of cumulative experience demonstrated by the higher consumption of the blocks in the second period.

2.3. TANSY RAGWORT

ORIGIN AND DISTRIBUTION

Tansy ragwort (Senecio jacobea), a dicotyledonous plant of the compositae family, is normally described as a biennial (i.e. it flowers, seeds, and dies between 12-24 months after germination), but it frequently behaves as a perennial if damaged (Harper and Wood, 1957; Schmidl, 1972; Popay and Thompson,1981). It is regarded as a pioneer species, well equipped to colonize open patches created by any type of environmental disturbance (Cameron, 1935; McEvoy, 1984).

Ragwort is originally from Europe and Western Asia. A native of Britain, it has been found in Norway and extends as far east as Siberia and as far south as North Africa. From Eurasia it has been introduced to U.S.A., Canada, Argentina, New Zealand, South Africa, and Australia (Harper and Wood, 1957; Schmidl, 1972).

Within the U.S.A. there are reports of ragwort presence in Oregon as early as 1922 (Snyder, 1972; Bedell et al., 1981). The plant was first observed in Tillamook County and later spread to most of Western Oregon, Western

Washington, and California (Snyder, 1972). Satellite and photography surveys showed tansy ragwort in almost 20% of 16 million acres of Oregon forest and rangelands by 1979 (Isaacson and Schrumpf, 1979). By 1981, the plant was reported in more than 112,000 acres of pasture in Western Washington, and in Idaho it was considered a serious potential weed problem (Bedell et al., 1981). Tansy ragwort can be found in recently logged areas, irrigated or nonirrigated pastures, woodland pastures, unused lands, perennial seed fields, and occasionally in alfalfa fields (OSU Ext. Serv.,1983).

TANSY RAGWORT INFESTATION: BIOLOGICAL AND ECONOMIC LOSSES

Tansy ragwort contains toxic compounds called pyrrolizidine alkaloids (PA) which cause a cirrhosis-like condition in the liver (Johnson, 1978).

Although ragwort poisoning is not recognized as a major veterinary problem in England (McLean, 1970), it is regarded as one of the most serious noxious weeds in most of the countries where it is found. In Victoria, Australia, more than half a million dollars (Aust.) are spent annually by landholders and the State on ragwort control (Schmidl, 1972).

Early studies on tansy ragwort recognized that the plant was injurious to farming interests by taking possession of large areas of land suitable for grazing and by poisoning of stock (Cameron, 1935). The same author reported that in New Zealand ragwort toxicity is known as Winton Disease, so-called from the area in Southland where it first appeared, causing heavy mortality of horses and cattle. In Pictou, Canada, the same malady is known as Pictou Disease, and in Norway it is known as Sirasyke (Harper and Wood, 1957).

Annual losses attributed to tansy ragwort in the cattle industry in Western Oregon were estimated at $1.2 million by 1971 (Snyder, 1972). Losses in other species were not included in this figure. More recent studies (Isaacson and Schrumpf, 1979) estimated losses of about $600,000 per year due to displacement of forage species alone, ignoring losses due to animal poisoning. M. Craig (personal communication) estimated current losses of $20 million a year in Oregon, attributed to ragwort contamination of seed crops, hay and silage, and lost forage. Losses suffered by the livestock industry are thought to be about $5 million annually.

TOXICITY

Tansy ragwort has been reported to have similar alkaloid concentration per unit of plant weight at all growth stages and in all plant parts (OSU Ext. Serv. 1983).

However, other sources reported the greatest concentration of alkaloids in the flowers, followed by leaves, roots, and finally stems (Bedell et al. 1981).

The toxicity mechanisms of tansy ragwort are still not well understood. It is believed that toxicity is due to the effect of at least 6 pyrrolizidine alkaloids. These are not toxic by themselves but are bioactivated by hepatic enzymes to pyrroles that react with hepatic macromolecules causing liver necrosis (Buttler et el., 1970; Swick et al., 1983). When enough conversion to pyrrole has occurred (liver damage is cumulative with time and dose), liver function becomes inadequate and the animal dies. Frequently, deaths are seen as long as six months after the animal last consumed ragwort, yet symptoms of poisoning may not appear until a week before death. Sub-lethal symptoms are almost unknown (Harper and Wood, 1957; Snyder, 1972; Bedell et al., 1981).

The toxic effect of ragwort differs among species. Cattle and horses are the most susceptible among livestock species, with a lethal dose of 4-8% of body weight. Sheep and goats appear the most resistant with a lethal dose between 200-300% of body weight (Cheeke, 1984).

CONTROL OF TANSY RAGWORT

It has been long known that this weed will chiefly infest waste land and pastoral areas of poor quality. On well-cultivated land it is absent. Good cultivation and farming prevent its establishment (Cameron, 1935). Among the cultural management recommendations given by Bedell et al. (1981) to prevent ragwort infestations are the use of high-yielding and vigorous pasture species, proper fertilization, maintenance of dense stands, and uniform grazing of pastures.

Mechanical control is one of the oldest methods used to eradicate ragwort, as reported by Poole (1938). He evaluated the effects of chipping, deflowering, cutting down, defoliating, and pulling the ragwort plants, and found that only the last method was even partially effective to eradicate the weed. Later, Harper and Wood (1957) found that plants pulled by hand left sufficient root fragments for extensive regeneration to occur from root buds. Although mowing at the flowering stage temporarily suppresses flowering and makes the pasture look tidier, it is not recommended because it encourages the development of perennial plants with multiple crowns (Popay and Thompson, 1981).

Chemical control has also been used. Brewster et al. (1978) reported adequate control of ragwort with the amine and ester formulations of 2,4-D applied in the fall or spring when the plant is in the rosette stage. Dicamba, Picloran, and Sodium Chlorate, used alone or in a mixture with Sodium Borate (Polyborchlorate), could be effective if the initial treatment is followed by repeated spraying and well-planned pasture management. Otherwise, control will only be temporary (Schmidl, 1972; Appleby, 1979; Bedell et al., 1981).

BIOLOGICAL CONTROL OF TANSY RAGWORT BY INSECTS

Several attempts have been made to eradicate tansy ragwort with insects. Most of the entomological work has been done with the Cinnabar Moth (Tyria jacobaea), the ragwort seed-fly (Hylemyia seneciella), and the ragwort leafminer (Phytomyza syngenesiae) (Popay and Thompson, 1981).

Tansy ragwort was kept under natural control on its native land by a wide rage of insects that coevolved with it and fed upon it. When ragwort was introduced into new areas the natural predators did not accompany the plant, making very fast expansion of the weed possible. The cinnabar moth (Tyria jacobaea) and the flea beetle (Longitarsus jacobaea) have been imported to Oregon to control tansy ragwort (Bedell et al., 1981).

Tyria feed on the foliage and flowers of ragwort during the late spring and summer. However, high humidity during the fall will promote plant regrowth from the root stock, and produce secondary flowering with viable seed (Bedell et al., 1981; Popay and Thompson, 1981; Cox and McEvoy, 1983).

It has been noticed that a dynamic balance of insect and plant population tends to be formed, making the total eradication of the weed more difficult (Isaacson, 1979). Stimac (1977) inferred from a model of the Senecio-Tyria system that compensatory growth of ragwort must be limited to intermediate levels in order to stabilize ragwort populations. With high levels of compensatory growth, Tyria grazing ceases to be limiting and an outbreak of the plant occurs. With very low compensatory growth, the plant population declines and the moth then becomes locally extinct. Subsequently, the plant population undergoes resurgence. Stimac concluded that successful control of ragwort with Tyria requires a stable and low equilibrium of both plant and insect populations.

The flea beetle goes into aestivation throughout the summer but becomes active during the fall, feeding heavily on ragwort roots. Feeding continues through May, giving the plants little opportunity to recuperate before the long dry summer which is when most of the plant mortality occurs (Hawkes and Brown, 1979). Thus, it appears that a combination of root attack during the fall and winter by Longitarsus, and heavy defoliation during the summer by Tyria and(or) sheep could be one of best strategies for biological control of tansy ragwort (Hawkes and Brown, 1979; Bedell et al., 1981).

SHEEP AS A BIOLOGICAL CONTROL AGENT FOR TANSY RAGWORT

In most of the literature consulted, it was stated that sheep will eat ragwort. Whether or not the animals have a preference for the weed is still controversial.

According to Aston and Bruce (1933), if adequate alternative food is available S. jacobaea is avoided by cattle and horses. However, during periods of drought when grass is in short supply cattle and horses will eat the plant. The same authors report that there is some evidence that mature cattle may develop a lethal addiction to the plant. There is no evidence for the same kind of addiction in sheep, but it has been often reported that sheep will eat tansy ragwort readily (Harper and Wood, 1957; Schmild, 1972). According to Cameron (1935), sheep are very fond of ragwort, especially when the plant is in the young rosette stage. He further indicated that lambs appeared to eat only the outer leaves, whereas adult sheep preferred to eat the crown.

Mosher (1979) emphasized the stage of growth or season as a factor associated with consumption of the weed by sheep. This might imply that the willingness to graze ragwort could be more a function of alternatives rather than the attractiveness of the ragwort itself. Mosher (1979) found that sheep graze tansy ragwort heavily during the summer when pastures and most of the other vegetation is dry and during the winter when forage may be generally short.

If ragwort is consumed only when there is a lack of alternatives, a dislike for it could be assumed, and therefore a period of adaptation is required when the animal is forced to consume it. It has been observed that the animals must become accustomed to the plant before eating it, and that when they have developed a taste for it they prefer the plant to other vegetation (Mosher, 1979).

The questions addressing the existence of preferences for ragwort in sheep have not yet been answered. Those questions have not been stressed in ragwort control research since for practical purposes it has been adequate to divide the infested fields up into small areas and to keep sheep grazing on them until the plants get very closely eaten (Cameron, 1935; OSU Ext. Serv., 1983). Mosher (1979) reported a unique case of a cattle producer who brought approximately 1500 ewes to her ranch to control ragwort. The animals were restricted to the infested area from late May until late September, and although it took the sheep about a month before ragwort became a substantial part of their diet, most of the plants that could be reached were stripped of leaves and blossoms.

The work of Sharrow and Mosher (1982) is the only trial in the literature designed specifically to evaluate the use of sheep as a biological control agent for tansy ragwort. A sample of 100 plants were monitored before and after being grazed by a group of cattle during the spring of 1977. The same procedure was conducted in another plot which was grazed by cattle during the spring and by sheep during the following summer. Only 30 plants (all reduced to leafless stubs less than 3 cm long) were found on the Cattle+Sheep grazed plot. The rest of the plants were not found, presumably grazed down by sheep. Estimated forage utilization in this plot was about 80%. On the Cattle-grazed plot, estimated forage utilization was about 20%. Fifty-seven plants were found undefoliated, 16 were found with all their flowers and leaves removed, and 27 plants were not found. These results indicated that intensive grazing by sheep can effectively reduce the ability of tansy ragwort plants to flower and produce seed (Sharrow and Mosher, 1982).

Whatever the method used to control tansy ragwort, it appears that it needs to be reapplied on a periodical basis rather than used only a single time. According to Schmidl (1972), sheep eat ragwort and suppress infestations to a certain extent, providing a reliable but temporary control.

According to Chippindale and Milton (1934), ragwort will recover following the removal of sheep even after 5-7 years of intensive grazing. Plants will begin to reappear in the first year after removal and the recovery will be complete by the second year. Ragwort seeds can remain dormant in the soil until the presence of suitable environmental conditions for germination. Chippindale and Milton (1934) found buried viable seeds in soils which had been undisturbed for 22 years.

In summary, a major proportion of the literature reported here presents the general theoretical and methodological grounds to induce food preferences. On the basis of those reports, it seems to be possible to induce ragwort preferences in sheep under natural grazing exposure. Furthermore, the use of sheep as a biological control agent for tansy ragwort provides a vehicle to understand the learning mechanisms of food preferences, and the use of behavioral sciences in solving animal production problems.

3. MATERIALS & METHODS

3.1. ANIMALS:

Eighty ewe lambs of five different genotypes were included in this trial as illustrated in table 2.

Table 2. Number of animals of each genotype used during the trial

No	GENOTYPE	
16	COOPWORTH X COOPWORTH	(CC)
16	POLYPAY X COOPWORTH	(PC)
16	SUFFOLK X COOPWORTH	(SC)
16	POLYPAY X POLYPAY	(PP)
16	SUFFOLK X POLYPAY	(SP)
80		

Prior to the experiment, lambs had no exposure to tansy ragwort nor any shrub type of plant. The animals were weaned at 80 days of age and grazed a combination of graminoids and legumes until the beginning of the trial.

3.2. DESIGNATION OF TREATMENTS:

Treatments consisted of two exposure periods to tansy ragwort: "Early Exposure" (EE), at approximately 6 months of age, and "Late Exposure" (LE), at approximately 15 months of age. One half of the animals were exposed during the early period. This half was randomly split into two groups, and one group was again exposed during the late period. The half that was not exposed during the early period was also divided into two groups with one of them exposed during the late period. Therefore, four treatment groups were created: animals who were exposed during both periods were regarded as treatment one (T1), those exposed only during the early period were treatment two (T2), those exposed only during the late period were treatment three (T3), and those not exposed during either period were treatment four (T4). Figure 1 illustrates the partitioning of animals to treatment groups.

Figure 1. Designation of animals to treatment groups

ORIGINAL POPULATION	EARLY EXPOSED		LATE EXPOSED	TREATMENT GROUP
16 CC 16 PC 16 SC 16 PP 16 SP	YES 8 CC 8 PC 8 SC 8 PP 8 SP	YES	4 CC 4 PC 4 SC 4 PP 4 SP	T1
		NO	4 CC 4 PC 4 SC 4 PP 4 SP	T2
	NO 8 CC 8 PC 8 SC 8 PP 8 SP	YES	4 CC 4 PC 4 SC 4 PP 4 SP	T3
		NO	4 CC 4 PC 4 SC 4 PP 4 SP	T4

TANSY RAGWORT FOR THE EXPOSURE PERIODS:

Plants used during both exposure periods were collected during the summer of 1985. Approximately 2300 Kg of ragwort plants were harvested by hand in the vicinities of Corvallis and Philomath, Oregon. A portion of the plants collected was fed fresh during the early exposure and the remainder was dried and converted into pellets for the late exposure period.

Plants were in a wide range of growth stages when harvested although the majority were flowering. Dry matter content was approximately 20%. Many plants were heavily infested with caterpillars of the cinnabar moth. Most of the caterpillars were removed by striking the plants.

Conserved plants were air dried in a covered concrete area, ground, and stored for eight months under dry conditions. The dried ragwort was then made into pellets of 1 cm diameter and 2 cm length.

FIRST EXPOSURE:

At the start of early exposure (July 27, 1985) animal average weight was 27.3 Kg and average age was six months. The initial population was randomly divided into two groups, each one containing equal numbers of animals per genotype. One group remained on pasture, the other was brought to the sheep barn and fed an estimated 0.45 Kg of fresh tansy ragwort per animal per day for a period of five days. Consumption of ragwort was encouraged by making the plants available in troughs before the normal feeding time. Enough trough space was provided to avoid feeding comptetition. The rest of the diet consisted of ryegrass screening pellets.

SECOND EXPOSURE:

Nine months later, on April 21, 1986, animal average weight was 43.2 Kg, and average age was 15 months. The two early groups were randomly divided in half and groups T1 and T3 were brought to the sheep barn for the late exposure. A mixture of equal parts of tansy ragwort pellets and grass-seed screening pellets were offered ad libitum for a period of six days with enough trough space to avoid feeding competition. Average estimated consumption of ragwort was 0.72 Kg/animal/day.

3.3. ASSESSMENT OF GRAZING PREFERENCES

Determination of grazing preferences was assessed during Spring of 1986 under abundant pasture conditions (Experiment 1), and again during Summer of the same year when amount and quality of pasture were limited (Experiment 2).

DESCRIPTION AND PREPARATION OF EXPERIMENTAL AREA

EXPERIMENT 1 (EXP.1)

The first trial was conducted from the 17th to the 27th of June, 1986, at the Oregon State University Soap Creek-Beef Cattle Ranch located 9 Km north of Corvallis, Oregon.

An area of approximately 2.5 ha with high natural concentration of tansy ragwort was mapped so that areas with homogeneous densities of ragwort could be identified. The experimental area was relatively flat, and represented a typical Western Oregon tall fescue pasture.

Six weeks before starting the trial, cattle were introduced into the grazing area in order to reduce the general height of the pasture and to make ragwort plants more conspicuous. Some ragwort plants were partially damaged by trampling but no grazing of them was noticed. The area was heavily infested with thistles (Cirsium arvense and Cirsium vulgare) which were removed by hand before the experiment. A list of the major plant species in the area is given in table A of the appendix. Estimated forage availability at the start of the trial was 2500 Kg DM/ha. This was done by random sampling using a small frame of known area.

After biomass determination, four areas with homogeneous ragwort density, each of approximately 700 m^2, were selected to serve as replicates. Each replicate was subdivided into four grazing cells to which the treatment groups of animals were assigned at random. Figure 2 illustrates the distribution of replicates and treatment group areas. Cells within replicates were located according to the natural distribution of tansy ragwort, but close enough to each other so that they all could be observed from a common viewing location. Grazing cells were of irregular geometrical shapes with an average area of 144 m^2. In one corner of each cell a small corral of 2 m^2 was placed to help in loading of animals and for confinement of sheep during the time they were not under observation. Cells were fenced with electrified netting, and wooden folding panels were used for the corrals.

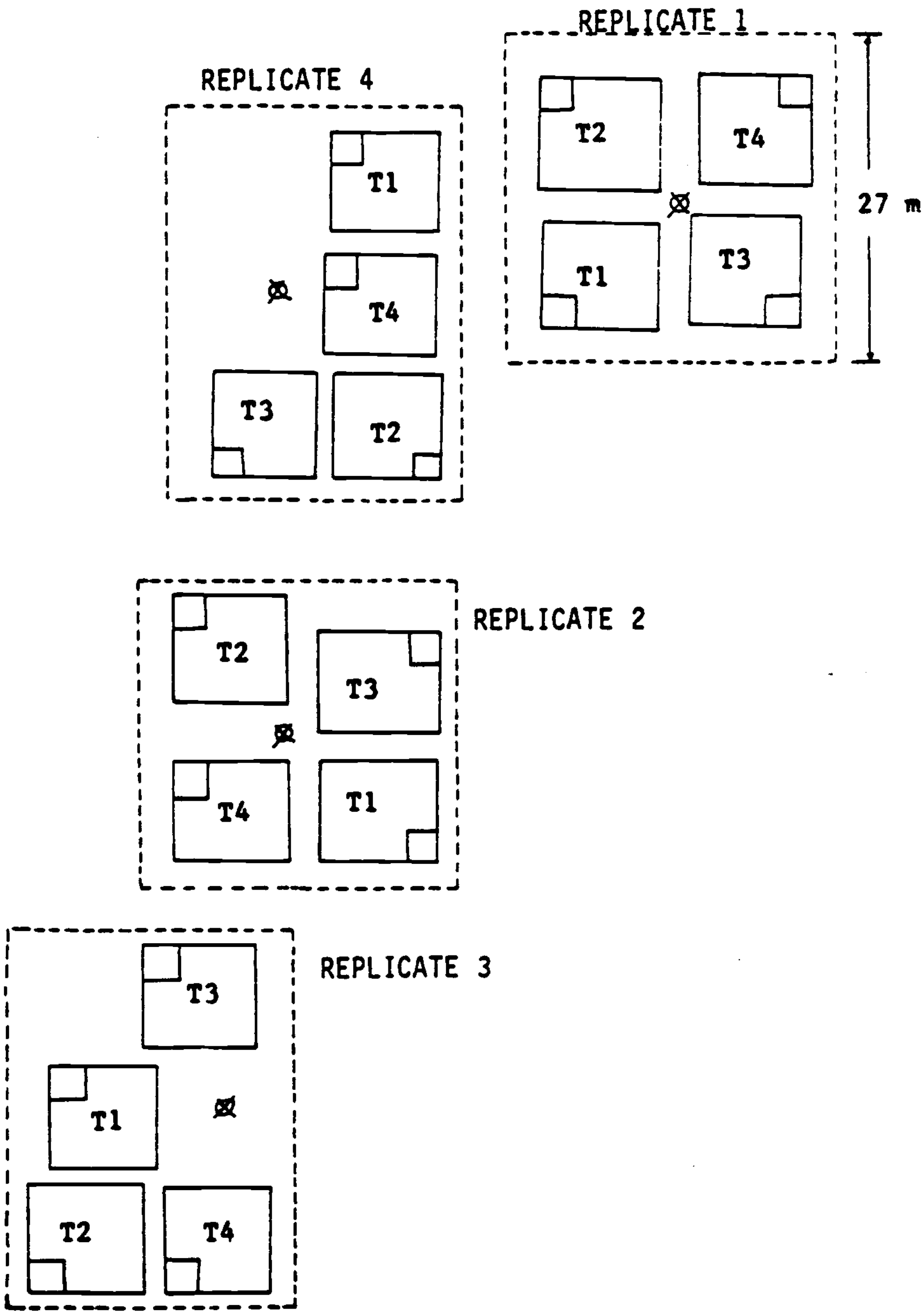


Figure 2. Distribution of grazing areas and designation of treatments for Experiment 1.

EXPERIMENT 2 (EXP.2)

The second trial with tree replicates was conducted from the 1st to the 8th of August, 1986, at the Soap Creek and Berry Creek areas at the Oregon State University Beef Cattle Ranch. The animals used in Exp.2 were the same as used in Exp. 1. The first replicate of this trial reused one of the grazing areas of Exp. 1 at Soap Creek, and the last two replicates were conducted at Berry Creek. Dipel (Bacillus thurintigienphis, variety kurftaki) was periodically sprayed on ragwort plants during July to control cinnabar moth on the grazing area of the first replicate.

The Berry Creek experimental location was hilly but size of replicates and cell grazing areas were comparable to those of Exp. 1. Biomass estimation was approximately 1200 Kg DM/ha for the first replicate (Soap Creek), and an average of 2900 Kg DM/ha for the last two replicates. Plant species present were approximately the same as described for the first experiment; however, density and size of ragwort plants were greater.

3.4. OBSERVATION TECHNIQUES

Grazing preferences were determined by two methods; one assessed what the animals were grazing (grazing observation), and the second what the animals had grazed (plant observation).

GRAZING OBSERVATION

The type of forage being ingested was determined by periodically observing the animals while grazing. The technique required rapid identification of the animal being observed and observation of the plant being ingested. Grazing observation records were of four types as shown in table 3.

Table 3. Type of grazing observations recorded during the trial

RECORDING	OBSERVATION
0	ANIMALS WERE NOT GRAZING
0'	ANIMALS WERE GRAZING. OBSERVATION NOT POSSIBLE BECAUSE OF VISUAL INTERFERENCE FROM OTHER ANIMALS OR PLANTS OR BECAUSE THE ANIMALS WERE FACING AWAY
1	ANIMALS WERE GRAZING PASTURE
2	ANIMALS WERE GRAZING TANSY RAGWORT

The recorded information was used to determine grazing preferences by expressing the number of times an animal was observed grazing ragwort as a proportion of the number of times the animal was observed grazing.

PASTURE OBSERVATION

This technique allowed determination of tansy ragwort preferences by observing plants before and after sheep grazing. Proportion of plants grazed and the severity of grazing gives an estimate of grazing preferences. The technique requires identifying precise location of plants so that the location could be found even if plants had been completely grazed. Grazing was visually estimated for each plant as a proportion of the size and shape of the plant before grazing. Plants were scored for grazing as shown in table 4.

Table 4. Ranges and scores of plant consumption used for the pasture observation technique.

% OF PLANT REMOVAL	SCORE
0- 5	2.5
5-10	7.5
10-20	15.0
20-50	35.0
50-100	75.0

Distribution of ranges is such that more precision is given to light grazing. With short grazing periods and abundance of biomass and other plant species, light grazing is more likely to occur. Consequently, higher precision at light grazing was accomplished by having a higher number of categories (i.e. smaller range per category) at the lower end of the scale. Since estimation of plant foliage removal was to be subjective, the observer gained previous experience in recognizing different stages of growth and proportion missing on ragwort plants. All estimations were done by the same person.

The average ragwort grazing score was calculated for each cell as the mean of individual plant scores.

3.5. CONDUCT OF THE EXPERIMENT

The day before grazing each replicate, the appropriate animals were removed from pasture before their normal afternoon grazing and held overnight with ad libitum water but no food. Animals were color marked on shoulders and hips according to their treatment and genotype. The observer was kept unaware of the relationship between colors and treatments in order to avoid bias during data collection.

On the day prior to grazing of each replicate, individual plants were identified in the grazing cells.

Plastic poles of the electric netting were used as reference for transects running from one side of the cell to the other. Plant locations were measured relative to the reference points. Average number of plants identified per cell was 40. On each grazing day animals were transported to the experimental area then unloaded and confined in the appropriate corrals until the observer was ready for observation. Although pasture was available to the animals inside the corrals, the amount was considered negligible. The corrals were opened for all animals to start grazing at the same time. Data collection started at approximately 8:00 a.m.

After a short adaptation period of one or two minutes, grazing observations were initiated and recorded on a tape recorder. Binoculars were used to assist in identifying what the animals were eating. The observer sat on a swivel stool elevated above the box of a truck. The vehicle was centrally located to allow easy observation of animals in the four cells being grazed.

Observation of each animal took only a few seconds. The five animals of each grazing cell were always observed in the same order to facilitate consistent recording. Average time for observing all twenty animals in a replicate was two minutes. Observation rounds were repeated until the animals stopped grazing. They were then returned to the corrals and held until the evening observation period commencing at about 6:00 p.m. The observation procedure was repeated until animals stopped grazing and were finally removed.

3.6. MONITORING OF TOXICITY.

Possible liver damage due to ragwort toxicity was monitored by serum determination of gamma glutamyl transpeptidase (GGT) and alkaline phosphatase (ALP) enzymes. Fifteen sheep randomly selected at the beginning of the trial were bled at the time of the first exposure, six weeks after the first exposure, and five weeks after the second exposure.

3.7. STATISTICAL ANALYSIS

The two null hypothesis evaluated in this experiment were:

i) There are no differences in ragwort preference of adult sheep that have been exposed to different combinations of early experience with this plant.

ii) Ragwort preferences are not affected by the genotype of the animal.

Several statistical analyses were used for the grazing observations. Data was initially evaluated using the unweighted analysis of means as described by Snedecor and Cochran (1967) in a 2x2x5 factorial arrangement with two levels of early exposure, two levels of late exposure and 5 genotypes. A standard analysis of variance was then utilized for the same factorial arrangement after applying the arc sine square root transformation to correct the data for non-normality (Snedecor and Cochran, 1980). Grazing observations were also analyzed using the Chi-square test of homogeneity for binomial samples (Snedecor and Cochran, 1980) and the logistic response function as described by Neter et al., (1983).

Pasture observations were analyzed with standard analysis of variance on a 2x2 factorial arrangement with two levels of early exposure and two levels of late exposure after correcting for non-normality using the arc sine square root transformation.

4. RESULTS

4.1. EXPERIMENT 1

GRAZING OBSERVATIONS

From a total of 2980 observations during the first experiment, 2454 (82.35%) corresponded to animals grazing pasture, 3 observations (0.001%) to animals grazing Tansy ragwort, and 523 observations (17.55 %) were made when the animals were either out of sight (7.99%) or when they were not grazing (9.56%). The three animals observed grazing ragwort were of different genotypes. Figure 3 depicts the number of observations in each category.

PASTURE OBSERVATIONS

The extent of ragwort consumption by the 4 treatment groups as measured by observation of the plants immediately before and after grazing is shown in figure 4 . A total of 647 plants were monitored for grazing during the experiment. Number of plants per cell ranged between 11 and 66; the mean was 40 plants per cell. There were no significant differences in ragwort consumption preferences between treatment groups. Plant consumption in the grazing cells in Exp. 1 is summarized in table 5.

Figure 3. Tansy ragwort preferences of four groups of sheep with different types of previous exposure to that plant, evaluated as percentage of total grazing observations per treatment group (Exp. 1).

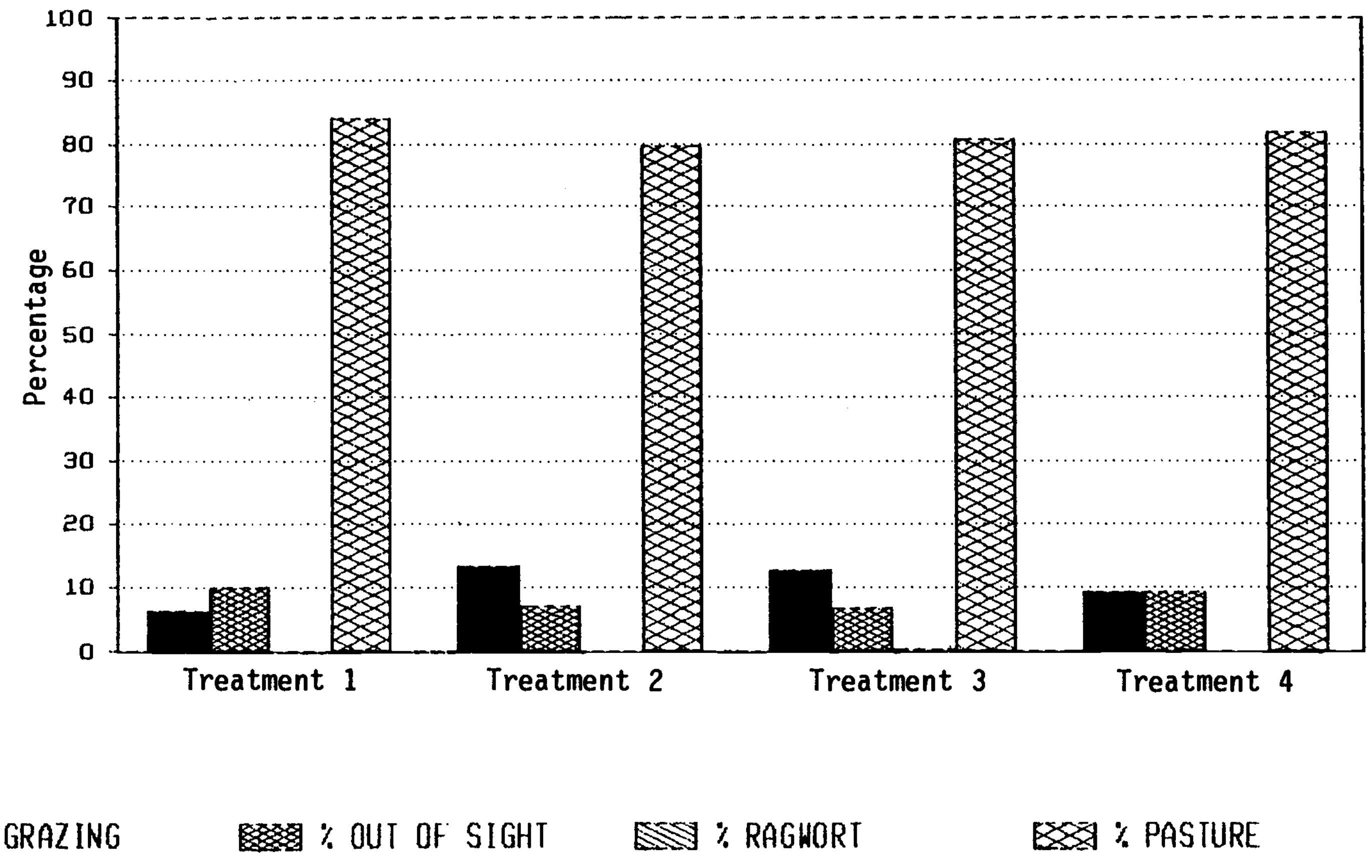


Figure 4. Tansy ragwort preferences of four groups of sheep with different types of previous exposure to that plant, evaluated as percentage of plants in each grazing category (Exp. 1).

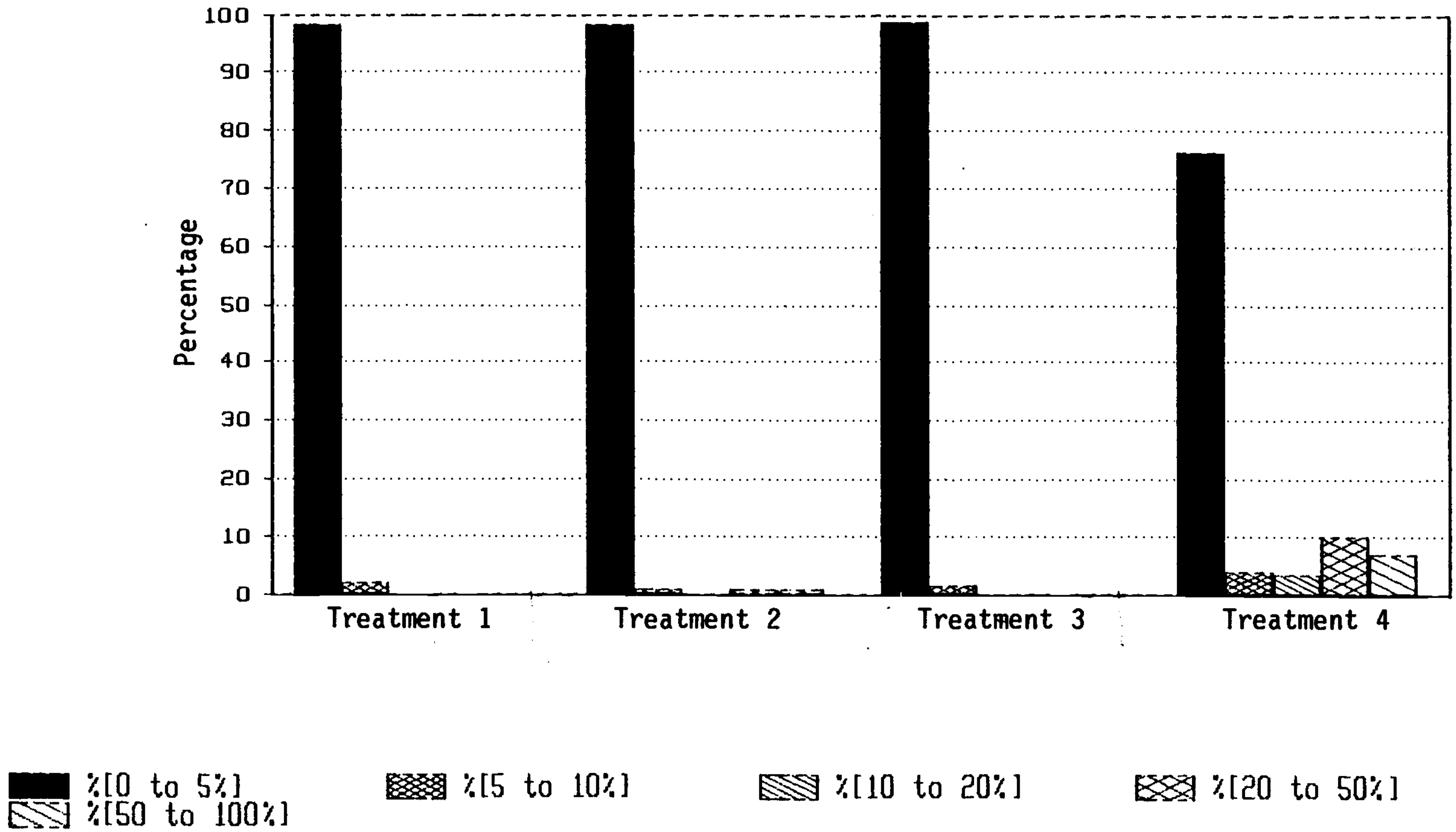


Table 5. Ragwort consumption in Exp.1 as indicated by number of plants in each of the grazing categories.

GRAZING CATEGORY (%)	TREATMENT			
	T1	T2	T3	T4
0-5	131	133	195	153
5-10	2	1	3	6
10-20	0	0	0	6
20-50	0	1	0	13
50-100	0	1	0	12

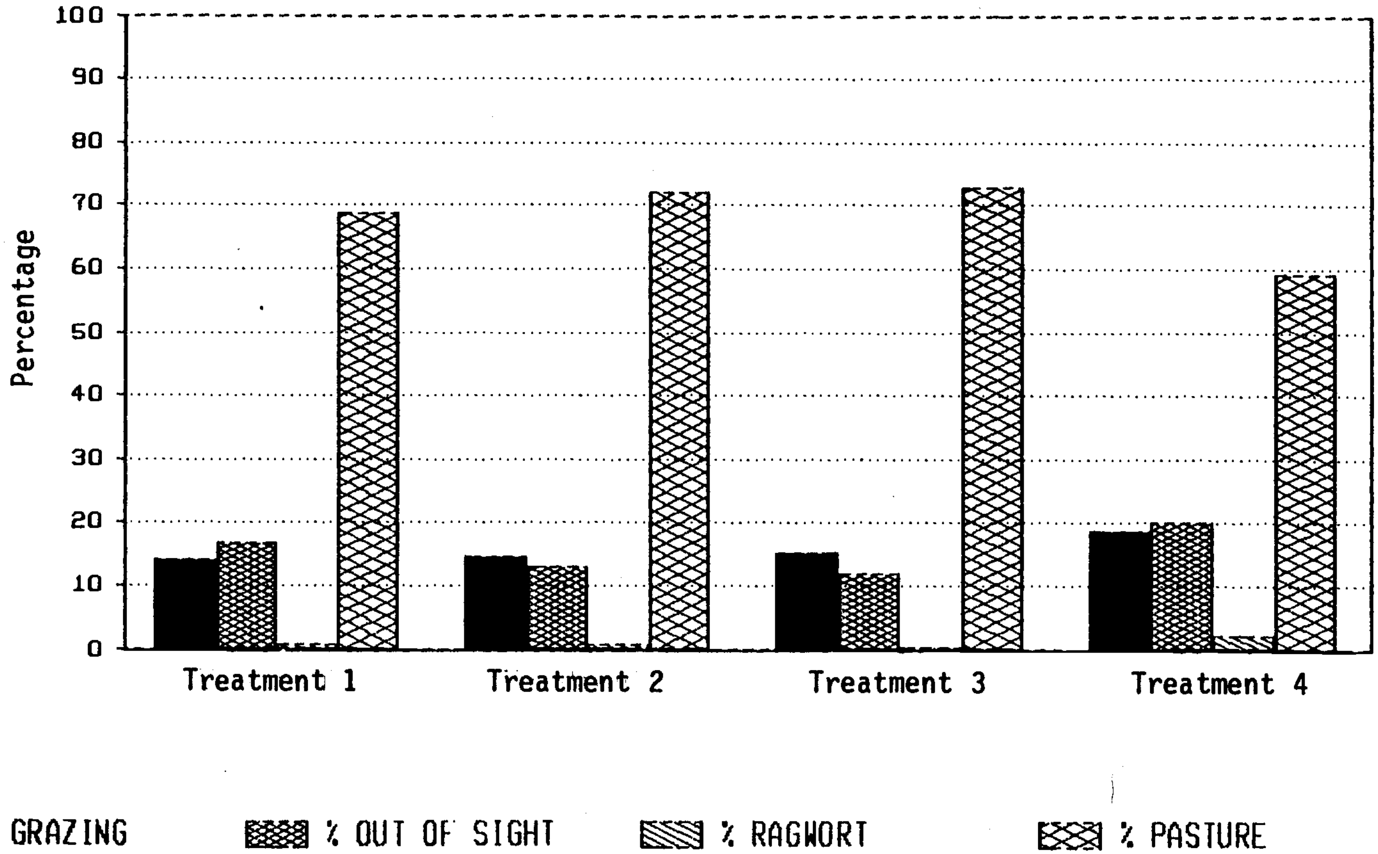
Considerable ragwort grazing occurred only in one cell during the whole trial (last replicate, treatment 4). From a total of 43 plants monitored in this cell, 12 (28%) had 50% or greater removal of the plant, 11 (25%) were grazed between 20-50%, 6 (14%) were grazed between 10-20%, 4 (9%) were grazed between 5-10%, and 10 (23%) were grazed between 0-5%.

4.2. EXPERIMENT 2

GRAZING OBSERVATIONS

In total 2300 observations were made; 1560 (67.83%) were of animals grazing pasture, 21 observations (0.91%) were of animals grazing ragwort, and 719 observations (31.26%) were of animals either not grazing (15.87%) or out of sight (15.39%). A breakdown of grazing observations by treatment group is summarized in figure 5. No significant differences were found between genotypes.

Figure 5. Tansy ragwort preferences of four groups of sheep with different types of previous exposure to that plant, evaluated as percentage of total grazing observations per treatment group (Exp. 2).



While main effects were not significant, the analysis of variance with unweighted cell means, the standard analysis of variance with transformed data, and the logistic regression function all showed an interaction ($p<.05$) between early and late exposure. The Chi-square test for binomial samples showed that treatment groups were not homogeneous ($X^2=16.11$, 3 df, $p<.005$).

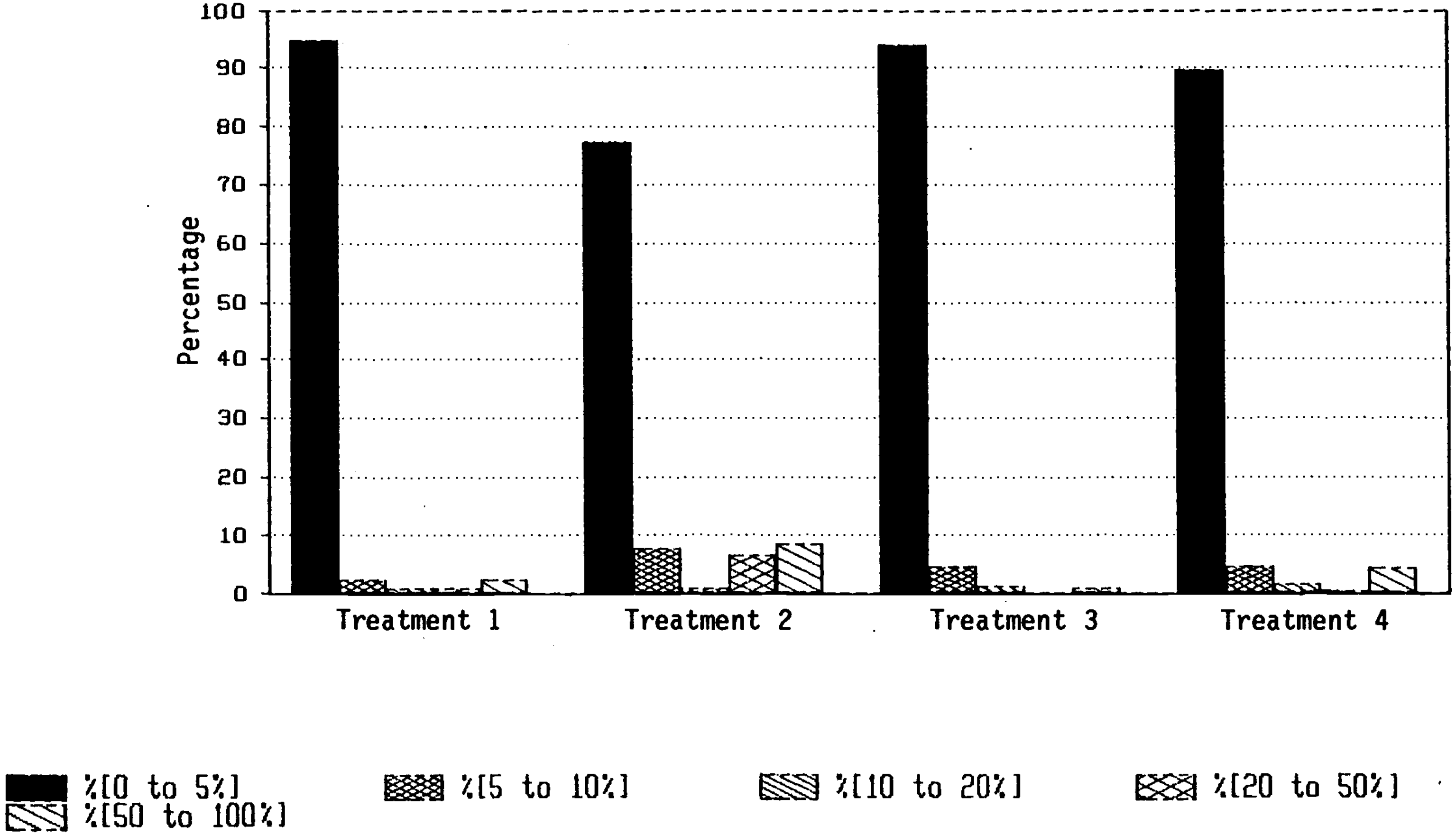
PASTURE OBSERVATIONS

Six hundred plants were monitored on Exp.2. Average number of plants sampled per cell was 50, and the range was 9 to 86. No significant differences were found between treatment groups. Only 45 plants in the whole experiment were grazed more than 10%. Figure 6 depicts the number of plants per grazing category for each of the 4 treatment groups.

4.3. INDICATORS OF TOXICITY

Neither of the two enzymatic indicators of liver damage showed any suggestion of injury to the ragwort exposed animals compared to controls.

Figure 6. Tansy Ragwort preferences of four groups of sheep with different types of previous exposure to that plant, evaluated as percentage of plants on each grazing category (Exp. 2).



4.4. OBSERVATIONS OF GRAZING ACTIVITY

RELEASING INTO GRAZING CELLS

Once the corrals were opened the animals moved quickly into the grazing cells but they appeared somewhat suspicious because of the novelty of the place. Although grazing began immediately, sheep looked around constantly and reacted strongly to activities around the grazing cells (reaction to the same kinds of activities was smaller later on). Initially, the animals tended to stay in a tight group, moving continuously while grazing. Tight groups remained in cases of disturbances, but the animals tended to spread out to graze when confidence was gained.

Preference for a particular plant was difficult to assess when the animals were bunched. Animals appeared to move without direction and grazing seemed random. When thistles or ragwort plants were encountered, the animals often appeared to smell the leaves and flowers without grazing them.

EFFECT OF COMPETITION

When there were no apparent disturbances animals seemed to prefer grazing individually. This was supported by the display of "rejection movements" shown by some animals when approached by others. The most graphic of these movements was a change in direction of either head or body toward the approaching animal, sometimes ending in bunting. In other cases, animals pushed laterally with their bodies as if trying to push away other animals grazing nearby. The "aggressive reaction" seemed to occur more frequently when environmental temperatures increased.

OTHER EXTERNAL FACTORS

Environmental temperatures seemed to affect both social interaction and grazing intensity. At higher temperatures animals seemed more irritable and showed less intensive grazing activity (they moved and grazed more slowly). For Exp. 1, estimated average temperature during data collection in the morning and evening were 19° C and 22° C, respectively. Average midday temperature was approximately 25° C. For Exp. 2, estimated temperature in the morning and evening were 21° C and 24° C, respectively. Average midday temperature was approximately 31° C.

Flies were another source of discomfort. The insects appeared when the temperature rose (approximately over 22° C) and in the absence of strong winds. Flies flew mostly around the heads of the animals, and were observed trying to get inside the sheep's ears. Sheep moved their heads, apparently trying to avoid the flies, and eventually moved away. If the insect disturbance persisted, the animals would get together in tight circles with their heads in the center. Sheep tried to keep their heads down, often underneath the head, neck or body of another animal as if trying to keep their faces and ears protected from the flies. Little or no grazing occurred at this time

5. DISCUSSION

5.1. EXPERIMENT 1

The almost complete absence of ragwort consumption during Exp. 1 was unexpected but strikingly clear. Significant differences between treatments would have led to rejection of the null hypothesis that treatment groups did not differ in ragwort preferences. The absence of ragwort grazing in this trial did not even allow statistical analysis of the data and thus comparisons were not possible.

Results of the pasture observations in Exp. 1 confirm the outcome of the grazing observations. The monitored plants were generally not grazed. However, animals from treatment 4 in the last replicate showed considerably more ragwort grazing than any other group during Exp. 1. Pasture observations in this grazing cell were consistent with the grazing observations. Given that the conditions of that particular cell were drier and with lower dry matter availability than the rest of the cells, it was thought that the experiment might have shown ragwort preferences if the evaluation had been done under conditions of food scarcity. In late summer when fewer pasture options are available, ragwort acceptance might be detectable. These were the considerations that prompted Exp. 2.

5.2. EXPERIMENT 2

The experimental setting for Exp. 1 was preserved for the conduct of Exp. 2. However, an unexpected plague of grasshoppers infested the area, leaving only one replicate area usable. Ragwort plants from this area, which became the first replicate of Exp.2, had been sprayed with insecticide to control Cinnabar moth. Residuals from the spray could have affected the flavor, and therefore acceptance of the plants. However, since there were no differences among replicates of Exp. 2 there is no evidence that the insecticide altered ragwort preferences.

Exp. 2 was conducted under conditions of poorer food availability and quality than Exp. 1. Tansy ragwort and thistles were practically the only green plants in the grazing cells. Nevertheless, consumption of ragwort was still very poor.

As in Exp. 1, only speculations can be made in light of the "lack" of results in Exp. 2. The significant interaction between early and late exposure found in this trial is probably not of biological relevance. As explained by Daniel (1978), when the statistical analysis of research findings gives statistically significant results, it should not be presumed that the discovery necessarily has any practical significance.

The very low rate of ragwort usage (21 of 1581 observations) during Exp. 2 clearly indicates low preference for ragwort. However, the non-random distribution of these data was the basis of the interaction. Strict interpretation of the interaction, without regard for the small amount of data involved, would suggest that animals which were "Early exposed" showed no ragwort preferences whether or not they were exposed the second time ("Late exposure"). On the other hand, animals which were not "Early exposed" showed greater grazing preferences if not "Late exposed", than if they were "Late exposed". While this interaction suggests that prior exposure to ragwort resulted in later aversion, the extremely low ragwort grazing incidence gives little confidence to such a conclusion.

In the present situation, animals had plenty of ragwort plants within the grazing cells and enough time to encounter them. The rest of the available food was dried pasture. Several times the animals were observed smelling and touching the weed. Yet less than one observation of ragwort consumption was made out of an average of 26 grazing observations made per animal per day. In many instances the animals were observed picking out small pasture leaves among the leaves of the ragwort plants. Totally ungrazed ragwort plants were found within the small corrals in which the animals were penned without food between the morning and evening observation periods. The appetite of the animals was evident by the "grazing to the ground" of pasture within the corrals; but still ragwort plants within corrals were not grazed. This behavior seems to contradict the findings in the literature reporting an immediate consumption of ragwort when sheep were introduced into a new infested area (Cameron, 1935; Harper and Wood, 1957; Schmild,1972).

If a farmer were to use sheep to control this weed it would be desirable that the animal would seek ragwort and graze a major fraction of it (e.g., 75% of the ragwort present) before grazing much of the other pasture. Since that degree of tansy ragwort consumption was not accomplished in this trial it could be said that the results are irrelevant for practical purposes in spite of the fact that a significant interaction was found.

The trial failed to induce grazing preferences for tansy ragwort by feeding it to lambs at 6 and (or) 15 months of age. Failure might be attributed to differences between the ragwort used for the exposure period and the ragwort used to measure preferences. This inconsistency was more likely to have affected the ragwort preferences of those animals assigned to the second exposure in which ragwort was offered as dry pellets.

Failure might also be attributed to the age at which the animals were exposed to ragwort. Compared with the reviewed literature, exposure periods in this trial were conducted relatively late in the life of the animals. Most of the earlier reports on induction of food preferences were conducted shortly after birth of the animal. This was based on the assumption that during the first few days after birth the animals were more sensitive to learn or to fix patterns of preferences. Keogh and Lynch (1982) did not find an effect of age at exposure on preferences when measured at adulthood, but the maximum age at exposure was only nine weeks after birth.

Another aspect that could have diminished the effect of the previous exposures was the absence of mothers. There is only one report in the consulted literature suggesting that sheep could develope feeding preferences by previous exposure to particular foods even without maternal presence at the time of the exposure (Lobato et al., 1980). Most reports in the literature recommend maternal presence during the "previous exposure" period as a way to enhance development of food preferences (Keohg and Lynch, 1982; Lynch et al., 1983; Green et al.,1984).

Ragwort consumption was imposed during both exposure periods. During the early exposure lambs showed clear willingness to consume the fresh ragwort plants, although this could have been the consequence of lack of any other green or fresh pasture (hay and ryegrass screening pellets were the other feed offered). During the second exposure, animals showed no attraction to the ragwort in the form of pellets. Sheep were able to choose the ragwort pellets out of a ration which contained equal parts of ragwort and ryegrass pellets. The total ration was reduced from 1 to 0.75 Kg of pellets per animal per day to force the animals to eat the ragwort fraction.

5.3. INDICATORS OF GRAZING PREFERENCE

Grazing and pasture observations together gave a better picture of grazing preferences than either of the two indicators alone. Their information was complementary. Plant observation was adequate in depicting what was grazed regardless of who did it. Grazing observations described who was grazing, yet the efficiency of this technique was found to be limited. Often the animals grazed and moved too fast for this "point grazing observation" to be able to record it. In some cases, plant removal due to grazing was recorded but the actual grazing was not observed. Thus, direct grazing observation (the way it was done in this trial) appears to be missing information.

Differential plant availability per cell was one of the major drawbacks of the plant observation technique. Comparisons between grazing cells requires as much homogeneity between cells as possible. Unfortunately, this requirement was only partially satisfied. The number of plants monitored did not reflect plant size, distribution, or density, all of which varied among cells. Some cells had so few plants that they were all included in the observed sample. Other cells had so many that the number of plants included depended upon labor and time constraints. Therefore, differential plant availability could present a possible bias for comparisons among grazing cells. As previously discussed, ragwort consumption in this trial was so limited that comparisons among treatment groups were not possible. Consequently, any possible bias due to differential plant availability was not detected. However, differential plant availability should be a critical consideration when designing scientific comparisons of grazing preferences under natural conditions.

5.4. CONCLUSIONS

It was concluded that the treatments evaluated in this experiment did not induce ragwort preferences in sheep. This was also true for all five genotypes tested. Failure to induce ragwort preferences in this trial may have been related to animal age at exposure, absence of mothers during exposure, differences between the form of ragwort at exposure and the form of ragwort at testing, or induction of aversion to ragwort due to unidentified stresses at exposure. The approach used in this experiment shows little prospect as a means of "training" sheep to selectively graze ragwort.

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APPENDIX

Appendix Table A. Plants present on experimental areas

COMMON NAME	SCIENTIFIC NAME
Annual fescue..................	_Vulpia_ sp.
Black garlic...................	_Allium nigrium_
Bull thistle...................	_Cirsium vulgare_
Canada thistle.................	_Crsium arvense_
Cat's ear or false dandelion...	_Hypochaeris radiata_
Curly-leaved dock..............	_Rumex crispus_
Dog tail.......................	_Cynosurus echinatus_
European or common centaury....	_Centaurium umbellatum_
Fall dandelion.................	_Leontodon autumnalis_
Meadow foxtail.................	_Alopecurus pratensis_
Orchard grass..................	_Dactylus glomerata_
Ox-eyed Daisy..................	_Chrysanthemum leucanthemum_
Parentucellia..................	_Parentucellia viscosa_
Perennial ryegrass.............	_Lolium perenne_
Silver hairgrass...............	_Aira carophylla_
Soft chess.....................	_Bromus mollis_
Tall fescue....................	_Festuca arundinacea_
Teasel.........................	_Dipsacus sylvestris_
Velvet grass...................	_Holcus lanatus_
Wall bedstraw..................	_Galium parisiense_
Wild carrot....................	_Daucus carota_

Appendix Table B. Analysis of variance according to the unweighted analysis of means for the grazing observations of experiment two.

SOURCE	DF	SS	MS	F	
REPLICATE	2	52.1857	26.0929	2.51	n.s.
EARLY EXP.	1	17.4744	17.4744	1.68	n.s.
LATE EXP.	1	45.9725	45.6725	4.43	*
EE X LE	1	48.4202	48.4202	4.67	*
ERROR	54	559.4972	10.3611		
TOTAL	59	722.5500			

* (P < 0.05)

Appendix Table C. Analysis of variance for the grazing observations of experiment two after the arc sine square root transformation for non-normality.

SOURCE	DF	SS	MS	F	
REPLICATES	2	79.5673	39.7837	2.30	n.s.
EARLY EXP.	1	26.7227	26.7257	1.54	n.s.
LATE EXP.	1	77.7373	77.7373	4.50	*
GENOTYPE	4	62.0819	15.5205	0.89	n.s.
EE X LE	1	96.9545	96.9545	5.61	*
EE X GENOT.	4	33.9806	8.4952	0.49	n.s.
LE X GENOT.	4	19.0274	4.7569	0.27	n.s.
EE X LE X G	4	8.4219	2.1055	0.12	n.s.
ERROR	38	656.3237	17.2717		
TOTAL	59	1,060.8473			

* ($P < 0.05$)