DEVELOPMENT AND COMPETITION OF CORN GROMWELL AND MUSK THISTLE IN WINTER WHEAT

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CHAPTER I

INTRODUCTION

Over 3 million hectares of hard red winter wheat (*Triticum aestivum* L.) are planted each year in Oklahoma (11,28). Oklahoma ranks second in hard red winter wheat production and fourth in total wheat produced in the United States (28). Musk thistle (*Carduus nutans* L.) and corn gromwell (*Lithospermum arvense* L.) are relatively new weed species in Oklahoma wheat fields. Therefore, little is known of their potential to become more serious weeds in small grains.

Lithospermum arvense L. has common names of corn gromwell, field gromwell and white iron weed, however corn gromwell is the Weed Science Society of America approved name and will be used throughout this thesis. Corn gromwell is found in Europe and in the temperate areas of the United States (19). Hajova and Krekule (19,20) reported that corn gromwell was well adapted to droughty summers and cold winters because of its ability to germinate and flower only under favorable growing conditions. Corn gromwell occurs in moderately dense populations in some northcentral Oklahoma fields. It is reported to be resistant or to have an intermediate response to phenoxy herbicides (2,12,46). However, the phenology of the species is not well known, and poor control may be related to improper application timing. Its competitive ability with wheat is unknown.

Two common names have been given to Carduus nutans L. i.e. nodding thistle and musk thistle. The common name accepted by the Weed Science Society of America and used hereafter is musk thistle. Musk thistle is native to Europe and Asia where it has even been grown as an ornamental plant. It was introduced into the United States in the late 1800's and has spread westward to 41 midwestern and southern states (6,24,38). Because musk thistle has become a severe problem in rangeland and pastures, 20 states have declared musk thistle to be a noxious weed species (33,38). In 1976, 52 counties in Oklahoma were reported to have economic or potentially economic infestations of musk thistle (14). Though musk thistle control has been studied for many years, it remains one of the major weed problems in rangeland and pastures (44). Many states, excluding Oklahoma, have initiated legislation requiring landowners and operators to attempt to control noxious weeds such as musk thistle (9,30).

Musk thistle is reportedly a biennial which may not develop a seed head until the second year of growth (18,41). However, it has been observed by Payne County, Oklahoma, farmers to produce seed before harvest in clean tilled wheat fields and is rarely grazed by livestock at any stage of growth. Because it is a robust species with seed spread by wind, and because causal observations indicated an annual growth habit in winter wheat, a better understanding of its phenology and competitive ability in Oklahoma winter wheat was felt to be needed.

In addition to chemical control of musk thistle, biological control strategies have been investigated (34). The musk thistle weevil Rhinocyllus conicus Froel. has been released in Canada and the United States for biological control of Carduus species (34). Surles and Kok

(49) reported that severe weevil infestations of terminal heads during early flowering inhibited seed production and reduced seed viability. This head weevil has been introduced into Oklahoma, but has not prevented musk thistle from spreading.

In row crops, shading from the crop reduces weed competition. The continuous grazing of wheat may eliminate or reduce the competitive ability of this crop, but the extent of such effects is currently unknown. In addition semi-dwarf wheat varieties are frequently suspected of being less competitive with weeds, but there is little data to support this hypothesis.

One objective of this research was to evaluate the competitive effects of various densities of musk thistle and corn gromwell, established at three monthly intervals in the fall, on winter wheat forage and grain yields. Other objectives were to determine the effect of the different transplanting dates on the growth and the reproduction of the weeds. Finally, by simulating grazing, the effect of light interception by the wheat canopy on weed growth was determined.

CHAPTER II

LITERATURE REVIEW

Plant Species

Wheat

Hard red winter wheat is a winter annual species which grows to a height of 60 to 120 cm. The inforescence is a terminal spike with two to five florets per spiklet. Individual spiklets are attached at each node of the rachis (3). The 3 million hectares annually seeded to wheat in Oklahoma is greater than the area seeded to all other cultivated crops combined (11). Also, hundreds of thousands of animal unit months of grazing are provided by wheat during the winter months (28). The optimum seeding date for grain production is between September 15 and October 15, however seeding dates may be extended through December if moisture is adequate (28). The optimum seeding date for forage production is August 22, with a reduction of 672 to 1120 kg/ha for every 2 weeks delay of seeding. The majority of Oklahoma wheat land is in continuous wheat production.

Corn Gromwell

Corn gromwell is a cool-season winter annual. Germination occurs in the fall usually after heavy rains when temperatures range from 10 to 20 C (1,19,20). This species overwinters as an emerging seedling or leaf-rosette and flowers in early spring with seeds ripening before summer (19,20). Corn gromwell reproduces by seeds inwhich 4 seeds are compacted into a nutlet surrounded by a calyx that rest on a basal stem which extend 25 to 50 cm at maturity. Leaves are simple, alternate, linear, and pubescent. Dense clusters of white flowers and seed calyx containing 4 small wrinkled nutlets are distinct characters used to identify this and other species of the Boragenaceae family.

Musk Thistle

Musk thistle reportedly prefers a moist alluvial soil and is found in pastures, roadsides, waste areas, lawns and in various crops. Musk thistle is primarily a biennial, but may grow as a winter annual or an annual under favorable growing conditions (16,36). Light enhances seed germination and seedling growth of musk thistle (16,36). Seedlings typically emerge throughout the fall and overwinter as compact rosettes. In addition, with moist conditions musk thistle may germinate in late winter or early spring. Early fall emerging plants will bolt in the spring and develop several seed heads in late spring or early summer, thus following the growth pattern of a winter annual. Plants that germinate in the winter months develop a rosette without bolting until the next year, ie. a biennial growth pattern.

The primary root system of musk thistle is a large fleshy tap root which is hollow at the surface of the ground. Musk thistle has many spiny leaves protruding from a basal rosette, and from erect stems after bolting. Leaves are alternate, glabrous, and coarsely lobed giving a wavy appearance. The flowers of musk thistle are composite, purple, and have a characteristic nodding appearance. Each flower is surrounded by the involucral bracts which narrow to a short point. Musk thistle has a determinate flowering pattern, with flowering initiating at the terminal head and progressing downward branch by branch (36). This flowering pattern allows musk thistle to flower over a 2 to 3 month period. Like many species of the Compositae family, musk thistle is a prolific seed producer. It produces 10 to 100 seed heads per plant with a total of 10,000 to 11,000 seeds of which 90% germination can be attained (36). The fully developed musk thistle plant stands 1.8 to 2.1 meters in height.

Biological Control of Musk Thistle

The possibilities of biological control of introduced thistles in North America have been investigated since 1959 (45). Musk thistle depends upon propagation by seed for survival and thus is vulnerable to organisms that interfere with seed production (32,34). The musk thistle weevil (*Rhinocyllus conicus* Froelich) has proven effective in reducing musk thistle populations in several regions of the United States (4,7,26,40,41,45). Also, Dowd et al. (13) reported that in the United States, the musk thistle weevil had no predators and is not significantly affected by paratization.

The musk thistle weevil is native to South Central Europe and North Africa (27). In 1967 host specificity studies were conducted in Europe to positively determine whether the head weevil was a pest to beneficial crops (21,22,23). Following these experiments the musk thistle weevil was released in 1968 in Canada and one year later in the United States. The first successful release site was in a musk thistle infested pasture in Virginia (45). Favorable results were not observed until 1973. By 1975 all sites except one showed at least a 90% reduction in musk thistle densities. Fifteen other states have released the musk thistle weevil for biological control of musk thistle (15).

Don C. Arnold[1] released 320 adult musk thistle weevils around the dam at Boomer Lake in Stillwater, Payne County, Oklahoma on May 20, 1975. A second release of 500 adults was made on June 19, 1975 at a site 1 mile east and 1 mile north of the original site. Through 1982 the musk thistle weevil was released at two additional sites in Tulsa County and Noble County, Oklahoma. Arnold reported increases in populations of the musk thistle weevil at all release sites by July, 1985. However, these releases have not prevented the development of an expanding musk thistle population in Payne County.

The musk thistle weevil is a member of the Curculionidae family which consists of more than 2000 species in North America (29). The adult weevil is dark brown with small yellow spots on it's back (35). They are 0.47 to 0.63 cm long with a prolongation of the head into a distinct snout (29,35). Chewing mouth parts are located at the tip of the snout, which enable the insect to feed on internal tissues of plants and provides places for egg depositions. The eggs are covered with a light brown substance that darkens as it dries. The larvae are light colored, fleshy, legless grubs, that usually feed on internal parts of the plant. Generally, each species has specialized feeding habits as well as being specialized in their host plants. The musk thistle weevil

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1. Arnold, Don C., Ento. Dept., Personal Interview. Oklahoma State University, July 2, 1985.

overwinters as an adult in plant residues at the base of thistle plants. In the spring, adults become active and mate, after which the female adults travel up the thistle plant to lay eggs on the external parts of the involucral bracts. Up to 20 eggs may be laid on a single flower head (51). After a 6 to 8 day incubation period the larvae hatch and burrow through the bracts into the receptacle. At this stage the larvae develop and feed on developing achenes inside the thistle head. Feeding by the larval stage, which lasts from 25 to 30 days, is the main process by which control is obtained (27,41). Schroder (45) reported that as many as 16 larvae can invade a single flower head. In addition to the destruction of the seed by larvae feeding, another method of control is obtained when pupal cells are formed from larvae pupation. This causes seeds to adhere to the pupal cell and therefore they are not available for dispersal (23,42). Rees (41) found the viability of unconsumed seed was also adversly affected. He reported that the germination of seeds from infested heads was inversly related to the degree of infestation. Following the pupation period, which last 8 to 14 days, the adults will emerge from the thistle heads and remain dormant during the overwintering period. This stage of the weevils life cycle usually occurs in the latter part of the summer.

Surles and Kok (48) found that the musk thistle weevil was most effective on Carduus genus, due to the synchronization of overwintering weevil emergence in the spring with bud development. Schroder (45) also reported that the musk thistle weevil prefers to ovipostion on early developing buds since the terminal head is the first to bloom and usually has the highest quality seed. They concluded that head feeding weevils feed on the most viable seed of the musk thistle plant

(25,31,34,48,49,50). However, later developing heads on the lateral branches of the thistle plant may be less suceptible to head weevil infestations, which indicates a weakness in the ability of the insect to control all seed production (23,26,34).

Integration of herbicidal and biological control of thistles can be implemented by relating the application of herbicides to insect and plant developmental stages (51). The herbicide 2,4-D is commonly used to control musk thistle (chemical names of all herbicides mentioned are in Table I). Application of 2,4-D prior to musk thistle blooming is reported to have no adverse affects on musk thistle weevil populations (31,52). However, there are varied reports of mortality of weevils when exposed to mowing or grazing of pastures (23,41). Rees (41) found that mowing the thistle plant was fatal to all larvae, but most pupa and adults were uneffected. In contrast, Hodgson and Rees (23) indicated that the thistle plants could be mowed without harming developing weevils.

Weed Competition

Weeds compete directly with crops for light, water, and nutrients (54). The extent of competition between a weed and a crop depends upon crop species, weed species, weed duration in the crop, time of growth in crop, and weed density (37). Weed competition in cereals generally reduces crop vigor, tillering, head size and kernel weight (8). Blackman and Templeman (5) concluded that under normal annual rainfall, competition between weeds and crops is usually for nitrogen and light with nitrogen the most important component in the competition. However, competition for light becomes important when weed height is greater than

TABLE I

COMMON AND CHEMICAL NAMES OF HERBICIDES

Common name	Chemical name
acifluorifen	5-[2-chloro-4-(trifluoromethyl)phenoxy] -2-nitrobenzoic acid
bromoxynil	3,5-dibromo-4-hydroxybenzonitrile
chlorsulfuron	2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin -2-yl)amino]carbonyl]benezenesulfonamide
clopyralid	3,6-dichloro-2-pyridinecarboxylic acid
cyanazine	2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl amino]-2methylpropaneitrile
dicamba	3,6-dichloro-2-methoxybenzoic acid
DPX-E8698	mixture of metsulfuron and DPX-M6316
DPX-L5300	methyl 2-[3-(4-methoxy-6-methyl-1,3,5-triazin 2-yl)-N-methyl-amino]carbonyl]amino]sulfonyl] benzoate
DPX-M6316	methyl 3-[[(4-4-methoxy-6-methyl-1,3,5-tiazin -2-yl-aminocarbonyl]aminosulfonyl]-2-thiophenecarboxylate
DPX-R9674	mixture of DPX-M6316 and DPX-L5300
fluorochloridone	3-chloro-4(choromethyl)-1-[3-(trifluoromethyl) phenlyl]-2-pyrrolidone
fluroxypyr	4-amino-3, 5-dichloro-6-fluoro-2-pyridyloxy acetic acid
ioxynil	4-hydroxy-3,5-diiodobenzonitrile

TABLE I (continued)

metsulfuron	2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino]carbonyl]amino]sulfonyl]benozoic acid
picloram	4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid
PPG-1013	5-(2-chloro-4-trifluoromethylphenoxy)-2-nitroacetophenone oxim-o-acetic acid, methyl ester
2,4-D	(2,4-dichlorophenoxy) acetic acid
2,4,5-TP	2-(2,4,5-trichlorophenoxy) propionic acid

crop height (5). Competition for water should be apparent any time moisture supplies are limited.

Challaich et al. (10) reported that faster emerging wheat cultivars intercepted more light thereby reducing germination and growth of common purslane and downy brome. In his research, Centurk 78 wheat reduced fresh weight of downy brome 50% over a growth period of 58 days. He felt that since the competitive ability of a crop plant is determined partly by its efficiency in intercepting light, faster growing cultivars could more effectively reduce weed germination and growth and aid other control methods.

Roeth (43) reported that where musk thistle has become established, the grazing capacity of pastures and rangelands could be reduced by 50% or more. Wheat forage and wheat grain yield reductions of greater than 18% where found with infestations of 36 or more corn gromwell plants/m^2 (53). Wells (53) also reported that at equal densities corn gromwell decreased winter wheat grain yield more than 4 other weed species ie. wild turnip (*Brassica tournifortii* Gouan), henbit (*Lamium amplexicaule* L.), amsinckia (*Amsinckia hipida* L.) and white fumitory (*Fumaria parviflora* L.).

Control of Musk Thistle and Corn Gromwell With Herbicides

Musk thistle can be controlled with herbicides when treated in the seedling or rosette stage of growth (17). The most commonly used herbicide for musk thistle control is 2,4-D. However, picloram and dicamba are also used extensively. Picloram at 0.14 kg/ha applied under adverse growing conditions in the fall gave better postemergence control of musk thistle rosettes than 2,4-D at 2.24 kg/ha or dicamba plus 2,4-D at 0.3 kg/ha and 1.12 kg/ha respectively (44). There were no differences between 2,4-D, dicamba plus 2,4-D, and picloram in control when applied to first year rosette stage musk thistle in the spring, since all treatments provide at least 90% control (44). The control obtained with these herbicides decreases rapidly after bolting occurs. However, the combination of clopyralid plus 2,4-D amine at 0.28 kg/ha plus 1.12 kg/ha respectively effectively controlled bolted musk thistle (17,18).

Corn gromwell was reported to be resistant to some herbicides such as picloram, 2,4,5-TP and 2,4-D amine (2,46). Also, corn gromwell had an intermediate response when categorized as resistant or suceptible to 2,4,D (12). However, 2,4-D low volatile ester at 1.12 to 3.68 kg/ha applied to corn gromwell that was beginning to bloom gave excellent control (2,46). However it should be noted that these rates exceed the recommended rates for use in winter wheat. Bromoxynil at 0.28, 0.42 and 0.56 kg/ha as well as ioxynil at 0.56 kg/ha gave 80 to 90% control of blooming corn gromwell (47). Also, fluorochloridone at 0.62 kg/ha and acifluorfen plus bromoxynil at 0.28 kg/ha each gave excellent control when applied to corn gromwell at the cotyledon to early bloom stage[2,3]. In that research, the more recently developed sulfonylurea herbicides such as chlorsulfuron and metsulfuron at 0.017 kg/ha only gave fair to good control of blooming corn gromwell.

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2. Fay, P,K. and W.E. Dyer. Summary of 1983 Weed Control Trials. (Dept. of Plant and Soil Sci. Montana St. Univ., 1983) p. 152

3. Fay, P.K. and E.S. Davis. (Summary of 1984 Weed Control Trials. Dept. of Plant and Soil Sci. Montana St. Univ., 1984) pp. 59-62.

CHAPTER III

METHODS AND MATERIALS

Effect of Musk Thistle Density and Transplanting Date on its Growth and Development in and Competition with Winter Wheat

Field experiments were established at the Agronomy Research Station, Stillwater, Oklahoma, on September 22, 1983 and September 21, 1984 on a Kirkland silt loam soil (Udertic Paleustolls) (Sa=21%, Si=55%, Cl=24%, OM=1.8%) to evaluate the competitive effects of musk thistle on TAM W101 wheat. A second objective was to determine the effect of transplanting date on the growth, development and reproduction of musk thistle. On September 6, 1983, 392 Kg/ha of diammonium phosphate (18-46-0) was applied to the experimental area. Even though the soil type was the same for both years, the pH in 1983 was 6.2 whereas in 1984 the soil pH was 4.9. Therefore on August 22, 1984, 1008 Kg/ha of hydrated lime was applied to the experimental area and disced into the soil. Also on August 23, 1984, 186 Kg/ha of diammonium phosphate (18-46-0) plus 280 Kg/ha of ammonium nitrate (34-0-0) were applied to the experimental area. The experimental design was a randomized complete block with a factorial arrangement of treatments with weed transplanting date at 3 levels and weed density at 6 levels as the factors. The experiment was replicated 4 times. The wheat was seeded with a 5 row, 23 cm row spacing, double disk opener cone seeder, at 320 kg/ha on September 22, 1983 and on September 21, 1984. To obtain seedling musk thistles, locally collected seeds were placed on multi-layered germination paper in germinating trays. Distilled water was applied to the paper until the paper was saturated. Then the seeds were placed in a germinator with a daily dark period of 16 hours. The germination temperatures for musk thistle seeds were 30 C days and 20 C nights. After 7 days the germinated seedlings were hand transplanted into 5 by 5 cm peat pots containing soil from the field experiment site. The pots were placed on a greenhouse bench where they received approximately 11 hours of sunlight daily. The daytime temperature was kept below 33 C and night temperature was maintained near 20 C. Seedlings were allowed to develop over a period of 5 days to the 2 true leaf stage in the greenhouse before transplanting in the field. After the wheat had emerged, the seedling weeds were transplanted between the wheat rows to establish weed densities of 0, 2, 4, 8, 16 and 32 plants/m^2. The weeds were placed between each of the 5 wheat rows and evenly spaced over a 1 m^2 area for each density. Each 1m^2 plot was seeded with one border row on each side and one meter long borders on each end (Figure 1). Musk thistle seedlings were transplanted into the wheat at three monthly intervals. Weed transplanting dates for 1983 were September 29, October 26, and November 22. For 1984, the weed transplanting dates were September 27, November 3, and November 30. Wheat growth stages in 1983 for each transplanting date were, 1-2 leaf, 5-7 tillers and 10-13 tillers for September 29, October 26, and November 22, respectively. Wheat growth stages in 1984 were 1-2 leaf, 3-4

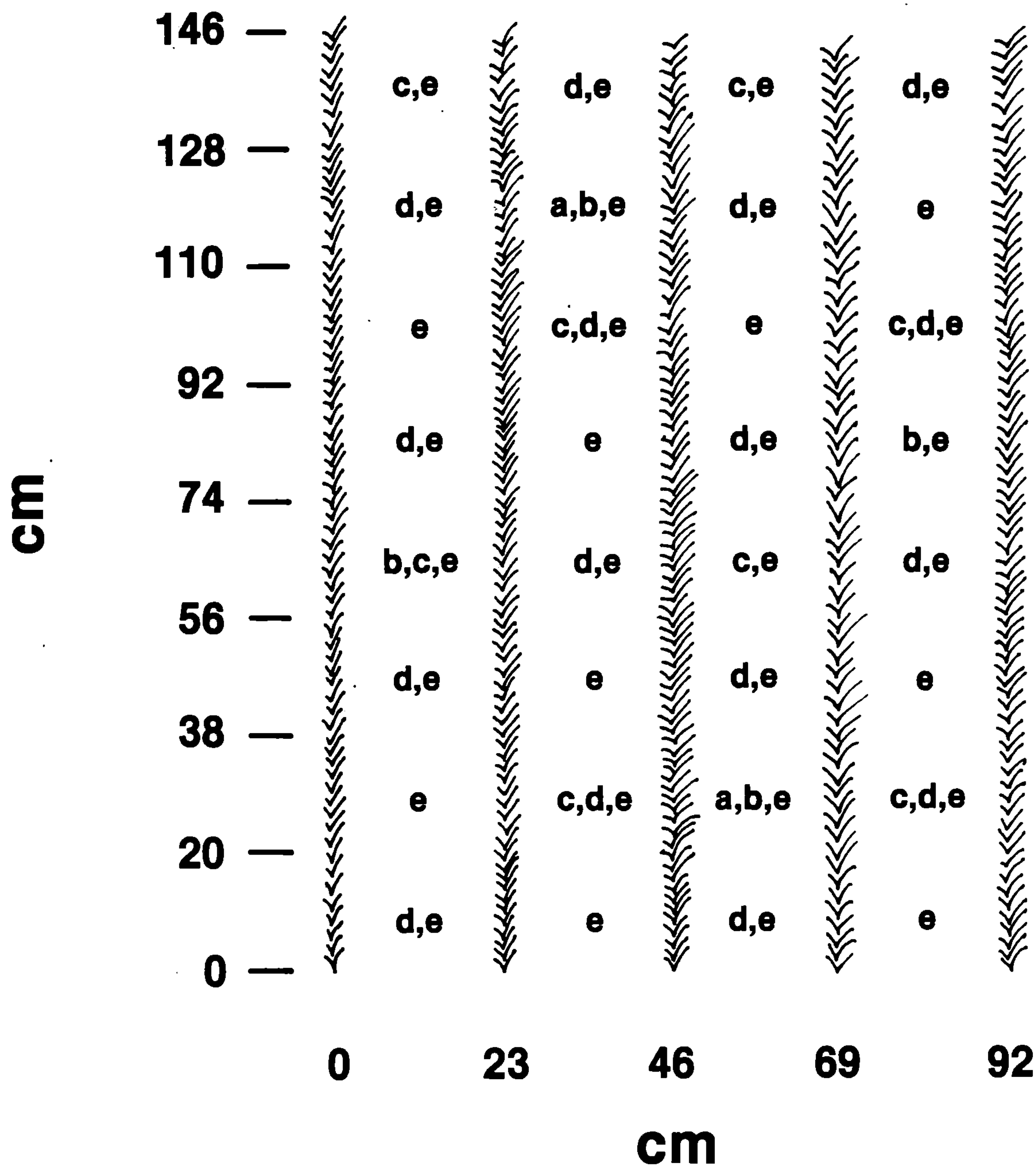

Figure 1. Position of transplanted weeds within a plot. "a" indicates location of weeds between wheat rows when weed density=2 plants/m^2, b=4 plants/m^2, c=8 plants/m^2, d=16 plants/m^2, e=32 plants/m^2. The 3 center rows were used for forage and yield data.

tillers and 5-7 tillers for the transplanting dates of September 27, November 3, and November 30, respectively.

During the growing season the growth of each weed was recorded by measuring plant height on June 5, 1984 and April 6, 1985, number of leaves produced on October 4, 1983, October 22, 1983, March 22, 1984, April 5, 1984, June 5, 1984, April 6, 1985 and June 2, 1985, rosette radius on March 22, 1984, April 5, 1984, June 5, 1984, April 6, 1985 and June 2, 1985. The rosette radius of the musk thistle plant was determined by measuring the longest leaf on the plant. All weeds were individually removed from the plots just prior to harvest of the wheat. Individual musk thistle plants were immediately weighed in the field to obtain the fresh weight, then placed in drying bins with a temperature of 43 C. After the plants were dried the dry weight, height, leaves/plant, rosette radius, heads/plant and head weevils/head were recorded. To further evaluate the musk thistle stage of maturity at wheat harvest, a maturity rating scale was devised to quantify the relative maturity level of each musk thistle seed head (Figure 2). Prior to weed harvest all seed heads on the individual musk thistle plant were visually categorized according to the scale illustrated in Figure 2. The seed head catergorization data was then analyzed as a 3 factor factorial with maturity stages at 5 levels, density at 5 levels, and transplanting date at 3 levels as the factors.

To better comprehend the effect of weed transplanting date on the growth and development of musk thistle population, a growth frequency distribution was conducted on the number of leaves produced/plant, rosette radius and the number of heads produced for each maturity stage. Observation dates for the number of leaves/plant and rosette radius were

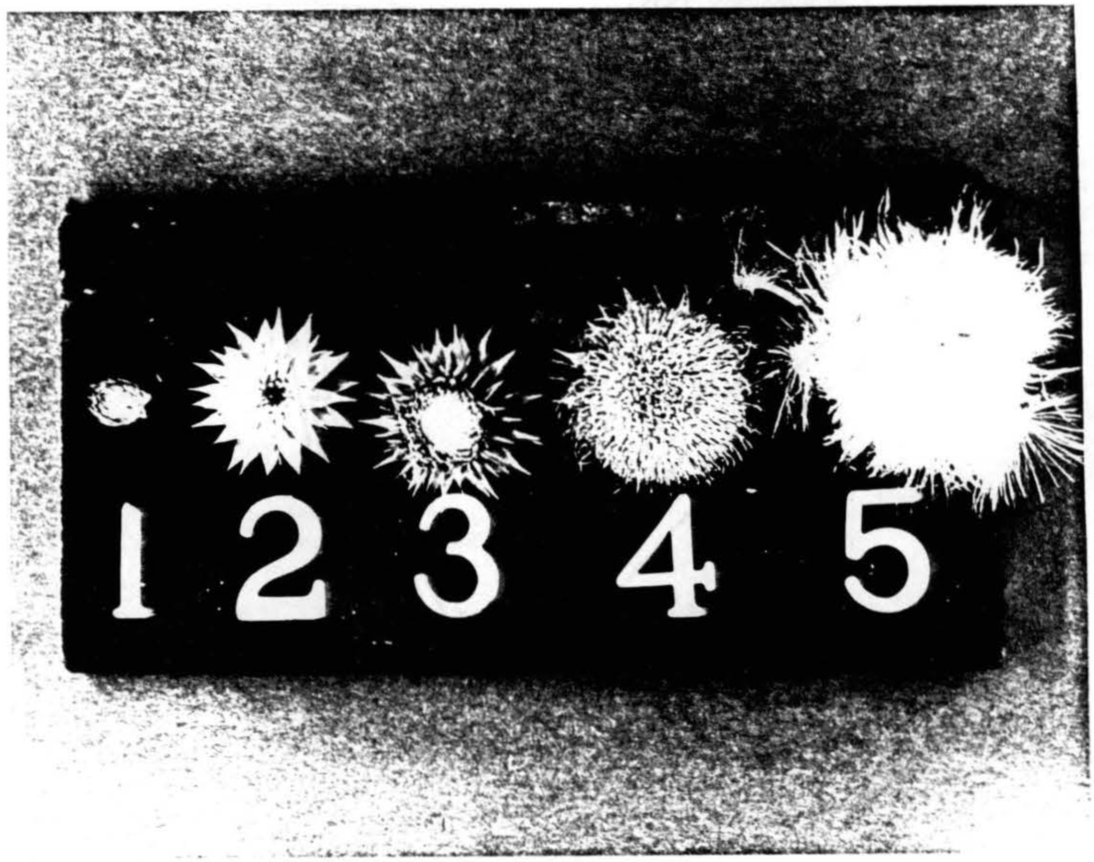

Figure 2. Musk thistle seed head maturity scale. Growth stage #1 = Bracts closed and no pappus present; Growth stage #2 = Bracts open and pappus first present; Growth stage #3 = Pappus fully present and rose colored; Growth stage #4 = Spiny bracts expanded with purple pappus; Growth stage #5 = Seed heads fully developed with mature dehiscence seed.

April 5, 1984, June 5, 1984, April 6, 1985 and June 2, 1985. Frequency distribution of musk thistle seed head maturity stages were observed on June 5, 1984 and June 2, 1985. Since the growth of the weeds transplanted in late September was much greater than those transplanted in October or November a further analysis of the weed density effect on September transplanted musk thistles was conducted. The musk thistle growth data for the September transplanting date was analyzed seperatly from the data collected from plants transplanted in October and November. An analysis of variance and regression analysis were then utilized to further examine the relationship between weed density and musk thistle growth of the September transplanted weeds. In the regression analysis, the September transplanted musk thistle growth data was regressed to fit a linear or quadradic model. The wheat in the plots was harvested with a small plot grain binder on June 5, 1984, and June 2, 1985. The wheat-straw bundles were dried in a greenhouse then individually threshed with a small plot combine to determine wheat grain yield.

Effect of Corn Gromwell Density and Transplanting Date on its Growth and Development in and Competition with Winter Wheat

Field experiments were established at the Agronomy Research Station, Stillwater, Oklahoma, on September 22, 1983 and September 21, 1984 to evaluate the competitive effects of corn gromwell on TAM W101 wheat. These experiments were also conducted to evaluate the effect of weed transplanting date on the growth, development and reproduction of corn gromwell. The soil preparation wheat seeding dates and methods, weed seedling germination methods, weed transplanting dates and weed transplanting pattern for these experiments were identical to those of the musk thistle density and transplanting date experiments. Statistical analysis procedures used in the corn gromwell density and transplanting date experiments were also the same as those used in the musk thistle density and transplanting date experiment. However, the germination temperatures used for corn gromwell were 10 C at night and 18 C in the day with a daily dark period of 16 hours.

During the 1983-1984 growing season corn gromwell growth was recorded by measuring leaves/plant on March 10, plant height on March 10, April 9, and June 5, basal stems/plant on April 9, and June 5, and flowers/plant on April 9, 1984. During the 1984-1985 experiment corn gromwell growth was recorded by measuring plant height on April 13, and June 2, basal stems/plant on April 13, and June 2, and flowers/plant on April 13, 1985. All corn gromwell plants were harvested just prior to wheat harvest. Individual corn gromwell plants were immediately weighed in the field to obtain fresh weight, then placed in drying bins at a temperature of 43 C. After drying, the dry weight, plant height, basal stems/plant and calyxes/plant were determined. In order to better understand the growth and development of the corn gromwell population a frequency distribution was conducted on the corn gromwell plant height and the basal stems/plant data collected on April 9, 1984, June 5, 1984, April 13, 1985 and June 5, 1985.

Effect of Simulated Grazing on Light Interception by the Wheat Canopy and its Effect on Weed Growth

In addition to the density experiments another set of experiments were simultaneously established on September 23, 1983 and September 21, 1984 to study the effects of wheat stature and simulated grazing on the growth and development of both corn gromwell and musk thistle. The methods of wheat planting and weed transplanting are identical to the previously disscussed density experiments. Also, since the experiments were located in the same area as the density experiment, the soil fertilization methods and application rates are the same as previously disscussed. Wheat harvesting dates of the grazing studies were June 5, 1984 and May 30, 1985. Again, the wheat harvesting procedures were identical to those of the density experiments. The experimental design was a randomized complete block with a factorial arrangement of treatments. Factors in this experiment were simulated grazing at 2 levels (i.e. with and without forage removed), weed density at 2 levels (0 or 32 weeds/m^2 and wheat stature at 3 levels. The experimental design for this analysis was a 2 factor factorial with variety having 3 levels and density having 2 levels. Each experiment was replicated 4 times. Osage, Newton and TAM W101 hard red winter wheats were selected to establish the wheat stature variable. Osage is classified as a late maturing tall statured wheat, whereas Newton and TAM W101 are early to medium maturing semidrawf wheats. Newton is typically 5 to 8 cm taller than TAM W101 and a few days later in maturing. Weed densities of 0 or 32 plants/m^2 were transplanted on October 14, 1983 and October 1, 1984, 21 and 10 days after the wheat was seeded, respectively. Simulated grazing will be referred to as wheat foraging throughout this thesis in order to properly describe the action effects of wheat foliage removal. Each year, forage was removed twice. Once during the fall and once in the spring. Foraging was performed by grabbing a hand full of tillers and quickly pulling them from the wheat plants much in the same manner as a cow would graze. In the 1983-1984 season, wheat foliage was removed on November 17, and February 24. The following year wheat foliage was removed from the appropriate plots on November 24, 1984 and March 10, 1985. The wheat growth stage of all varieties was approximately 7 to 9 tillers in November, 1983 and 10 to 13 tillers in March, 1984. In 1984-1985 the wheat was somehwat smaller in November as to the previous year, with 4 to 5 tillers, however on March 10, 1985, the wheat had from 6 to 8 tillers. The weed forage was not removed because cattle do not eat musk thistle and typically graze down a wheat row, skipping weeds between the rows. Wheat forage fresh weight, dry weight, plant height and nitrate content were determined after each foraging. Wheat foliage from each foraging treatment was used to determine the nitrate concentration of the wheat. Plant nitrate concentration was determined using the nitrate electrode procedure (39). Following each wheat foraging, the effect of forage removal on light penetration to weeds was determined by recording light intensity (micro-$E/m^2/sec$) just above the wheat canopy and at ground or weed level (below canopy) between 11 a.m and 1 p.m. on essentially cloud free days. In plots with weeds not present, the light sensor was placed on the soil surface, whereas in plots with weeds present the sensor was placed at the apex of the weed. Percent light interception was calculated using the following formula:

$$\%\text{light interception} = \left[1 - \left(\frac{\text{light reading below the canopy}}{\text{light reading above the canopy}}\right)\right] \times 100$$

The growth and development of corn gromwell was determined by recording plant height on April 6, 1984, June 5, 1984, and June 2, 1985, basal stems/plant on June 5, 1984, and June 2, 1985, flowers/plant on April 6, 1984, and November 25, 1984, calyxes/plant on June 5, 1984 and June 2, 1985.

Musk thistle growth and development was determined by recording plant height on June 5, 1984 and May 30, 1985, leaves/plant on February 17, 1984, April 5, 1984, June 5, 1984 and May 30, 1985, rosette radius on February 17, 1984, April 5, 1984, June 5, 1984 and May 30, 1985, heads/plant on June 5, 1984 and May 30, 1985 and musk thistle weevils/head June 5, 1984 and May 30, 1985. On June 5, 1984 and May 30, 1985 each musk thistle plant was catergorized according to it's stage of maturity. Musk thistle plants were rated as being in a rosette, bolting, or heading stage of growth. The number of plants in each growth stage was analyzed as a 3 factor factorial experiment with growth stage at 3 levels (rosette, bolting and heading), variety at 3 levels and the foraging treatment at 2 levels. The weeds were individually removed from the plots immediately prior to wheat harvest and weed growth determined using the same methods as described for the density and transplanting date experiments. In May, 1985 the relative maturity of each musk thistle seed head prior to wheat harvest was determined by visually catergorizing each head on an individual musk thistle plant (Figure 2). Also, the frequency distribution of the occurrence of each head maturity stage was determined on June 2, 1985. The analysis of the maturity stage rating is the same as previously described.

Effect of Land Management on Musk Thistle Seed Head Production and Musk Thistle Weevils/Plant

On July 7, 1983, July 10, 1984 and July 11, 1985 a survey was conducted in Payne County, Oklahoma, to determine the degree of infestation as well as the environmental preference of the musk thistle weevil. Six locations were choosen for the environment variable and the same locations were sampled for all three years of this research. These included a conventionally tilled wheat field, grazed unimproved pasture, grazed improved pasture, hay field, roadside, and an unimproved pasture (not mowed or grazed). Wheat planting dates for the conventionally tilled environment were September 13, 1982, September 20, 1983 and September 4, 1984. At each location five musk thistle plants were randomly selected and each individual seed head was examined. To determine the degree of infestation and the environmental preference, the number of heads per plant as well as the number of weevils/head were recorded. The experimental design used to compare weevil population data was a randomized complete block in a factorial arrangement. The factors were years at 3 levels and environments at 6 levels. Five musk thistle plants were randomly selected at each location, therefore the sample size was five. The experiment was replicated 5 times.

Evaluation of the Emergence Patterns of Corn Gromwell and Musk Thistle

An experiment was initiated October 1, 1984 to observe the emergence patterns of corn gromwell and musk thistle in the fall. This experiment was located adjacent to the competition and grazing studies previously mentioned. Two hundred seeds of each weed species were seeded into 30 by 30 cm plots. The seeds were incorporated to a depth of approximately 1 cm using a hand garden tool. Weed emergence was determined by counting and then removing the emerged seedling corn gromwell and musk thistle. Emergence data was only collected when at least one weed seedling had emerged. Data collection dates included: October 11, 15, 19, 29, November 7, and 24. The experimental design was a randomized complete block with four replications. The data was statistically analyzed.

Control of Musk Thistle

An experiment was conducted in the spring of 1985 at the North Agronomy Research Station (Efaw Farm), Stillwater, Oklahoma to evaluate the efficacy of several herbicides on musk thistle. The site had been prepared for fall wheat seeding using conventional tillage but no crop was actually seeded. Treatments particulars are in Table II. At the time of application the musk thistle population was in the rosette growth stage. However, there was a range of musk thistles diameters, therefore individual plant diameters were categorized as being < 10 cm in diameter, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm or > 50 cm. The percentage of the total musk thistle population for each of the diameters are reported in Table II. Musk thistle control was evaluated visually. A herbicide treatments are in Table LI. The experimental design was a randomized complete block with 3 replications. All data was statistically analyzed.

TABLE II

CONDITIONS FOR MUSK THISTLE CONTROL SCREENING EXPERIMENT AT STILLWATER, (1985)

Location:	North Agronomy Research Station, Stillwater, Oklahoma
Soil:	Easpuri loam (Sa=33%, Si=34%, Cl=33%) OM=1.2%, pH=6.0 Flurentic Haplustolls
Application equipment:	Compressed air bicycle sprayer
Carrier volume (l/ha):	367
Spray boom:	Four 11004 nozzle tips on 50 cm spacing
Treatment particulars:	
Application stage[1]:	Postemergence
Date:	March 3, 1985
Air temp ($^\circ$C):	12.2
Soil temp ($^\circ$C):	10.5
Soil moisture:	Good
Sun:	Cloudy
Wind (km/h):	4-5

[1]Musk thistle diameters range at the time of application were:

% of population	diameter (cm)
8	<10
22	10-20
32	20-30
28	30-40
7	>50

CHAPTER IV

RESULTS AND DISCUSSION

Effect of Musk Thistle Density and Transplanting Date on its Growth and Development in and Competition with Winter Wheat

Weed density had little effect on the growth and development of musk thistle in 1983-1984 (Table III). Since there were no weed density by transplanting date interactions between weed density and transplanting date, the data comparing densities is averaged over transplanting date. Weed density had no effect on rosette radius, leaves/plant or heads/plant on October 4, 1983, October 22, 1983, March 22, 1984, April 5, 1984 and June 5, 1984. However, the mean dry weights of the musk thistles transplanted at densities of 8, 16, and 32 plants/m^2 were significantly less than those grown at a density of 2/m^2. There was not a difference in dry weight/plant between thistles transplanted at densities of 4 and 32/m^2 (Table III). The reproductive ability of musk thistle was also not affected by weed density, since there were no significant differences in musk thistle heads/plant on April 5, 1984 or June 5, 1984. No musk thistle weevils were found in 1983-1984.

Since the growth of musk thistle plants transplanted in September was much greater than that of the October and November plants, a further investigation was conducted on the relationship between weed density and

TABLE III

EFFECT OF WEED DENSITY AVERAGED OVER TRANSPLANTING DATES ON THE GROWTH AND DEVELOPMENT OF MUSK THISTLE (1983-1984)

	Oct. 4, 1983[1]	Oct. 22, 1983	March 22, 1984		April 5, 1984			June 5, 1984 (Weed Harvest)						
Musk Thistle Density	Leaves /Plant	Leaves /Plant	Rosette Radius	Leaves /Plant	Rosette Radius/	Leaves /Plant	Heads/ Plant	Plant ht.	Rosette Radius	Leaves /Plant	Fresh wt./ Plant	Dry wt./ Plant	Heads/ Plant	Weevils[2] /Plant
(weeds/m^2)			(cm)		(cm)			(cm)	(cm)		(g)	(g)		
2	3.0	5.7	8.8	9.0	9.7	7.7	0.2	23.0	10.7	15.1	38.6	8.9	1.4	0
4	3.1	6.1	8.0	9.2	9.6	8.2	0.3	29.2	10.4	13.7	19.5	4.7	1.1	0
8	2.9	6.0	7.8	8.7	9.4	7.9	0.3	24.7	9.8	11.8	12.7	3.2	0.7	0
16	3.1	5.9	6.8	8.5	8.9	7.0	0.3	22.8	8.7	12.6	20.2	4.6	0.9	0
32	2.9	6.0	6.7	7.8	8.9	13.6	0.3	27.5	9.9	13.1	16.7	3.8	0.8	0
L.S.D. 0.05=	(NSD)	(NSD)	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	21.8	4.1	NSD	—

[1] Measurements on October 4, 1983 and October 22, 1983 are from only the September transplanted musk thistle.

[2] Refers to the number of musk thistle weevils per musk thistle plant.

musk thistle growth of the September transplanted musk thistle. Therefore the September transplanted musk thistle growth data was separated from that of the October and November transplanting dates (Table IV). Among the September transplanted thistles, there were no differences due to density in rosette radii or leaves/plant on the dates of October 4, 1983, October 22, 1983, March 22, 1984, April 5, 1984 and June 5, 1984. Also, density had no effect on the heads produced/plant on either April 5 or June 5. Although the weight of musk thistles growing in a density of 2/m^2 was greater than all other densities, the r^2 value was 0.02 for the dry weight regression analysis. This reveals that due to the great variability between musk thistle plants a clear relationship between density and weed growth is difficult to attain.

Early spring observations in 1984 revealed that averaged over density, rosette radii and leaves/plant of September transplanted musk thistle were signficantly greater than that of October or November transplanted musk thistles (Table V). Because of substantial apparent differences in the rate of development within the population the data on growth was further categorized to gain a better idea of the proportion of the population that developed at different rates. Musk thistles transplanted on September 29, 1983 had rosette radii varying from 5 to over 40 cm with 1 to more than 16 leaves/plant on April 5, 1984. Seventy-two percent of the September transplanted thistles had developed a rosette radius of at least 20 cm (Figures 3 and 4). Seven percent of these plants had a rosette radius of 10 cm or less and 42% had 2 leaves or less. In contrast over 96% of the October and November transplanted musk thistles had rosette radii less than 10 cm with less than 2

TABLE IV

RELATIONSHIP OF MUSK THISTLE DENSITY TO THE GROWTH AND DEVELOPMENT OF SEPTEMBER TRANSPLANTED MUSK THISTLES (1983-1984)

	Oct. 4, 1983	Oct. 22, 1983	March 22, 1984		April 5, 1984			June 5, 1984 (Weed Harvest)						
Musk Thistle Density	Leaves /Plant	Leaves /Plant	Rosette Radius	Leaves /Plant	Rosette Radius	Leaves /Plant	Heads/ Plant	Plant Height	Rosette Radius	Leaves /Plant	Fresh Wt./ Plant	Dry Wt./ Plant	Heads/ Plant	Weevils/ Plant[a]
(weeds/m^2)			(cm)		(cm)			(cm)	(cm)		(g)	(g)		
2	3.0	5.7	15.7	15.5	17.4	13.5	0.9	65.6	17.4	29.2	109.5	25.5	4.2	0
4	3.1	6.1	14.2	15.0	17.3	14.8	1.0	85.6	13.7	25.9	52.4	12.5	3.4	0
8	2.9	6.0	13.6	14.6	16.6	13.8	1.0	70.1	11.9	22.6	34.6	9.2	2.1	0
16	3.1	5.9	11.9	14.3	15.6	11.9	1.0	65.5	11.6	23.3	55.5	13.0	2.9	0
32	2.9	6.0	10.4	11.7	14.8	30.2	1.0	75.0	10.9	23.9	45.0	10.7	2.3	0
L.S.D. 0.05 =	(NSD)	(NSD)	(NSD)	(NSD)	(NSD)	(NSD)	(NSD)	(NSD)	(NSD)	(NSD)	(NSD)	(12.5)	(NSD)	—

Regression equation[b] : dry weight/plant (June 5, 1984) $\hat{y} = 14.40 - 0.11\ x^c$ ($r^2 = 0.02$)

[a]Refers to the number of musk thistle weevils per musk thistle plant.

[b]Only regression equation and r^2 values with significant L.S.D. values are given.

[c]X is equal to the number of musk thistle plants/m^2 .

TABLE V

EFFECT OF WEED TRANSPLANTING DATE AVERAGED OVER WEED DENSITY ON THE GROWTH AND DEVELOPMENT OF MUSK THISTLE (1983-1984)

	Oct. 4, 1983	Oct. 22, 1983	March 22, 1984		April 5, 1984			June 5, 1984 (Weed Harvest)						
Date of Musk Thistle Trans-planting	Leaves /Plant	Leaves /Plant	Rosette Radius	Leaves /Plant	Rosette Radius	Leaves /Plant	Heads/ Plant	Plant Ht.	Rosette Radius	Leaves /Plant	Fresh Wt./ Plant	Dry Wt./ Plant	Heads/ Plant	Weevils/[1] Plant
			(cm)		(cm)			(cm)	(cm)		(g)	(g)		
Sept. 29, 1983	3.0	5.9	13.2	14.2	16.3	16.9	0.97	72.3	35.2	24.9	59.4	14.1	3.01	0
Oct. 26, 1983	—	—	5.4	6.4	6.3	5.2	0.01	2.7	8.2	8.0	3.1	0.7	0.02	0
Nov. 22, 1983	—	—	4.3	5.4	5.3	4.5	0.00	1.3	10.7	6.8	1.7	0.3	0.02	0
L.S.D. 0.05=	—	—	1.0	1.0	0.7	11.4	0.10	5.5	8.1	1.9	8.5	1.6	0.2	—

[1]Refers to the number of musk thistle weevils per musk thistle plant.

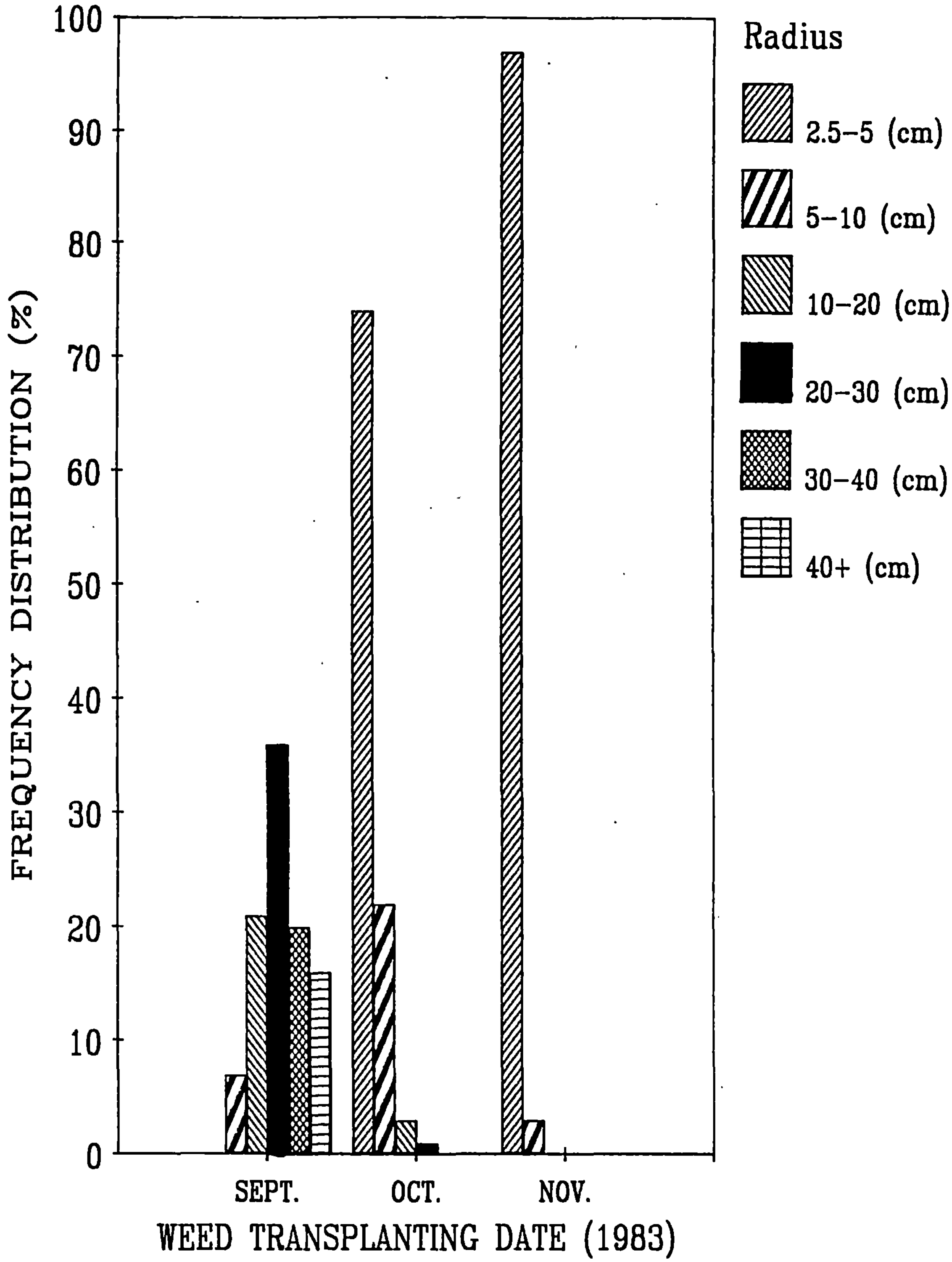

Figure 3. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on the Frequency of Occurrence of Plants With Various Ranges of Rosette Radii on April 5, 1984

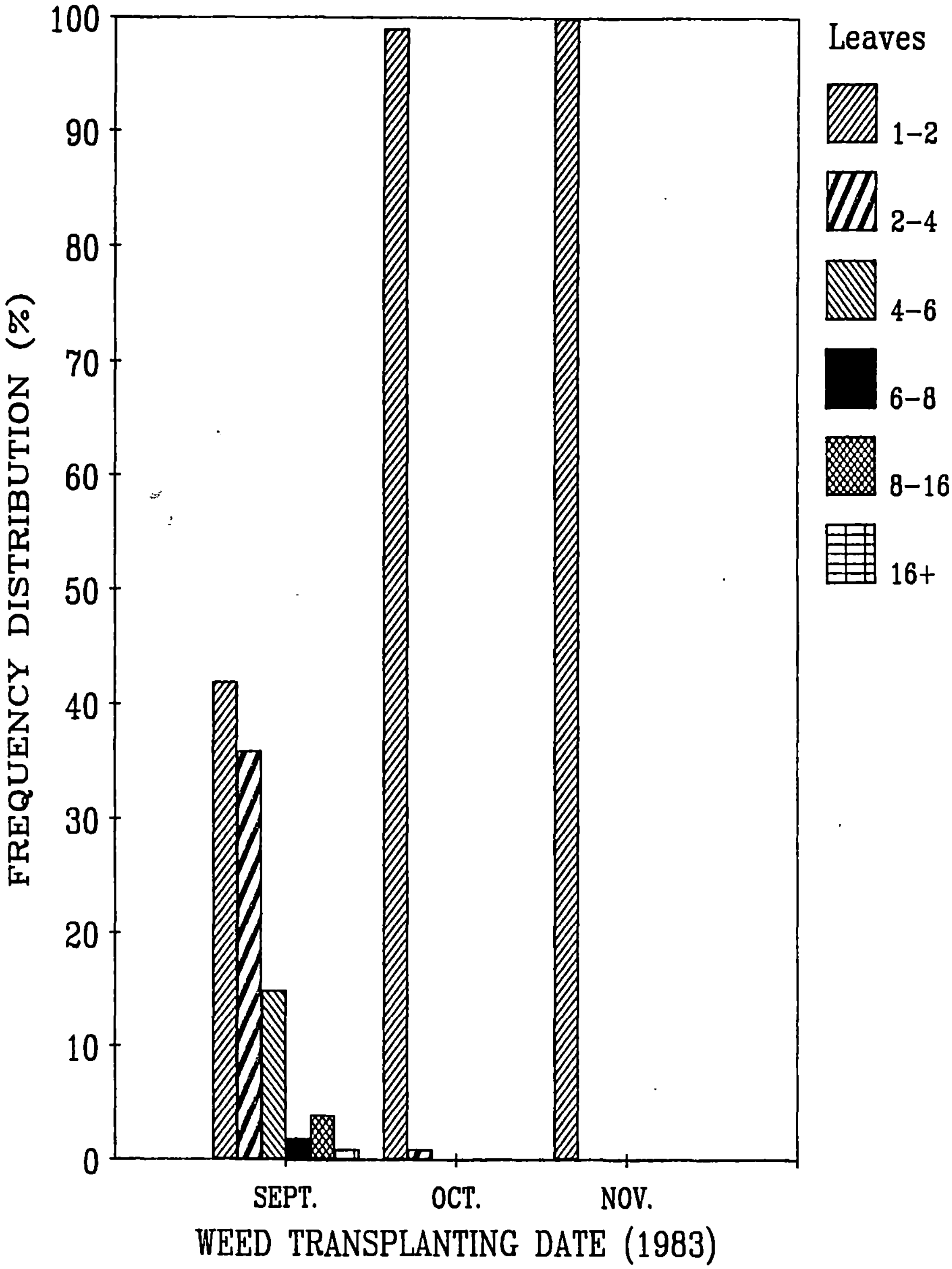

Figure 4. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on the Frequency of Occurrence of Plants With Different Numbers of Leaves on April 5, 1984

leaves/plant. This indicates that very little growth occurred on musk thistles during the winter and early spring.

The variability between plants within transplanting dates was not as apparent by June 5, 1984 as it was on April 5, 1984 (Figures 4 and 5). On June 5, 74% of the November transplanted musk thistles had a rosette radius of less than 20 cm, whereas the September and October transplanted musk thistles had 12 and 42% respectively of their populations with rosette radii less than 20 cm (Figure 5). Of the September transplanted musk thistles 88% had developed a rosette radius of at least 20 cm and 98% of the same population had developed 8 or more leaves/plant by wheat harvest on June 5, 1984 (Figures 5 and 6). On June 5, October and November transplanted musk thistles only had 5 and 0% respectively of their populations with more than 16 leaves/plant (Figure 6).

By April 5, 1984 the September transplanted musk thistles had developed an average of almost one head/plant whereas only two of 248 musk thistles transplanted in October had a head in April. None of the November transplanted musk thistles were able to initiate a seed head by April (Table V). This same trend was present on June 5, 1984, at which time the September transplanted musk thistles had an average of 3.01 heads/plant and October and November transplanted musk thistles had an average of 0.02 heads/plant respectively.

A significant head maturity stage by weed transplanting date interaction was observed when the plants were harvested on June 5, 1984. Musk thistles transplanted September 29, 1983 were able to develop some heads with mature seed by June 5, 1984, whereas October transplanted musk thistles only developed a few heads with bracts closed by June 5 and November transplanted musk thistle failed to develop heads at any

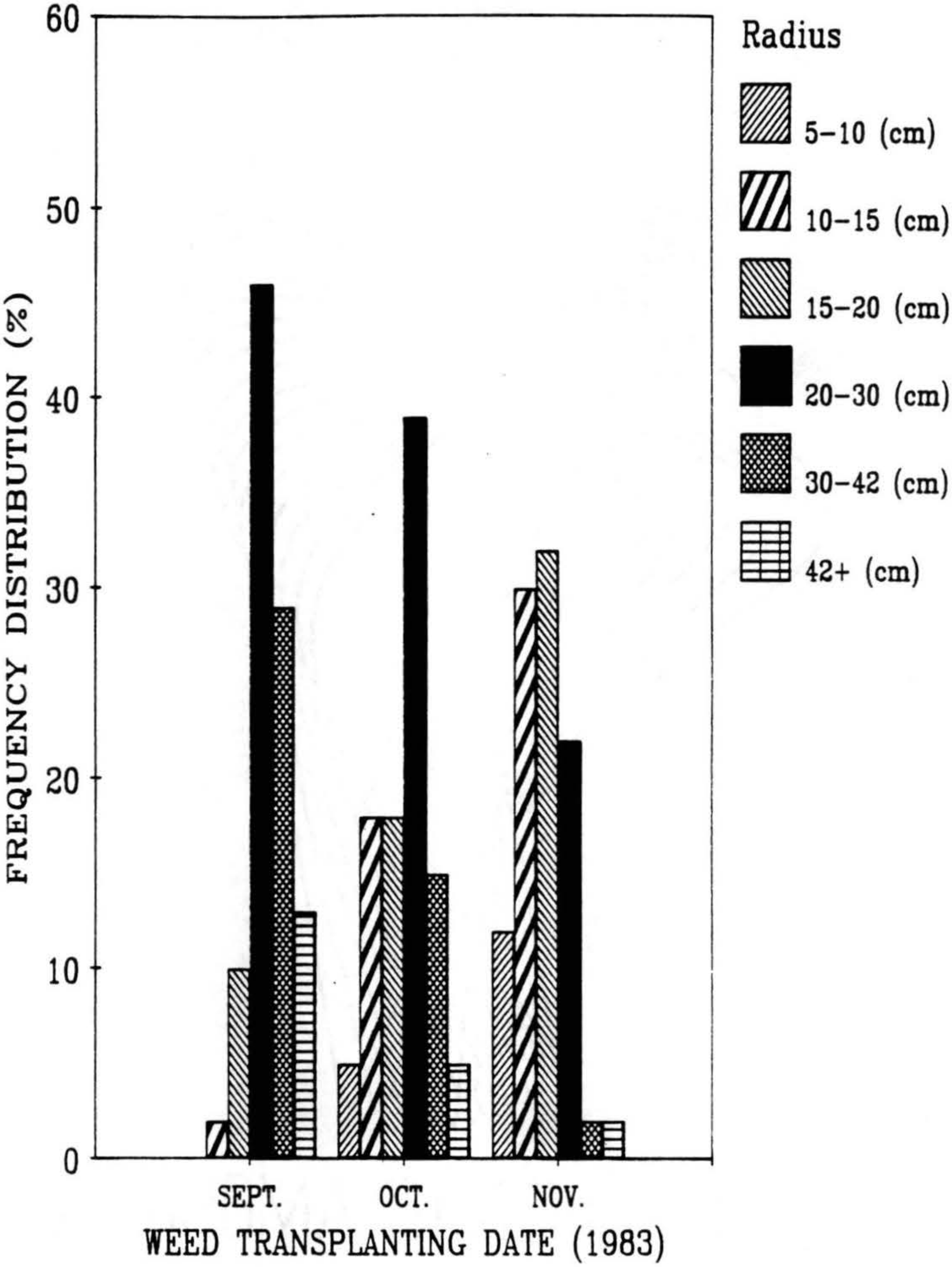

Figure 5. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on the Occurrence of Plants With Various Ranges of Rosette Radii on June 5, 1984

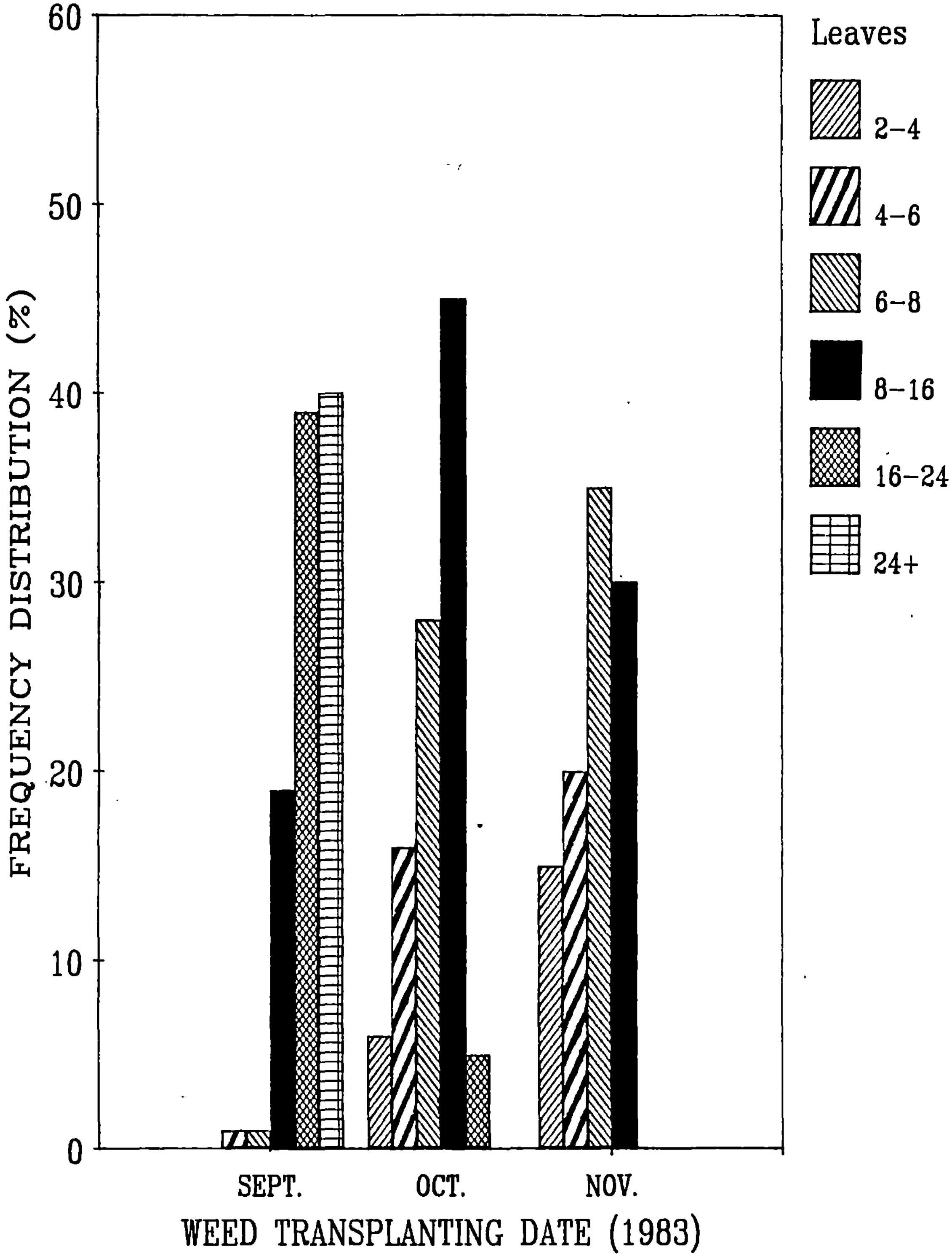

Figure 6. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on the Occurrence of Plants With Different Numbers of Leaves on June 5, 1984

maturity stage (Table VI). Of the musk thistles transplanted on September 29, 1983, heads with bracts closed were more numerous than any other head maturity stage. Also, heads with the pappus present were more numerous than heads with bracts open. The indicated interaction in the data is actually just due to variation in the maturity of heads on the September transplanted plants.

To further investigate the variation of head development in the musk thistle population, the various head maturity stages were converted to a percentage of the population for each individual transplanting date. Of the musk thistles transplanted during September, October and November, 57%, 92% and 100% respectively failed to develop a head by June 5, 1984 (Figure 7). At least 20% of the population of the September transplanted thistles had heads at each maturity stage by June 5, 1984 (Figure 8). However at the same time, of the plants that did develop heads in October, only 12% developed heads with bracts closed and 6% with heads with either pappus present or expanded. The November transplanted thistles did not develop any heads by June 5, 1984.

In 1984-1985 there was not any significant interactions present between weed density and weed transplanting date in the growth and development data, therefore in the discussion of main effects weed densities were averaged over weed transplanting dates and weed transplanting dates are averaged over weed densities. In the 1984-1985 musk thistle density experiment, weed density seemed to affect musk thistle plant height on April 6, 1985, but not the rosette radius or number of leaves/plant. Plant height of the musk thistles growing at the density of 16 plants/m^2 was significantly less than all other densities with the exception of the 32 plants/m^2 density, but no significant differences occurred in plant height on June 2, 1985. There

TABLE VI

EFFECT OF WEED TRANSPLANTING DATE ON THE RELATIVE MATURITY OF MUSK THISTLE HEADS AT WHEAT HARVEST (JUNE 5, 1984)

Musk Thistle Transplanting Date	Head Maturity[1]				
	Bracts Closed	Bracts Open	Pappus Present	Pappus Expanded	Mature Seed
	Number of heads per plant at each maturity stage				
September 29, 1983	1.60	0.30	0.50	0.30	0.38
October 26, 1983	0.03	0.00	0.00	0.00	0.00
November 22, 1983	0.00	0.00	0.00	0.00	0.00

L.S.D. 0.05 for comparing maturity stage by transplanting date interaction = 0.20

[1] Musk thistle maturity stages are illustrated in Figure 2.

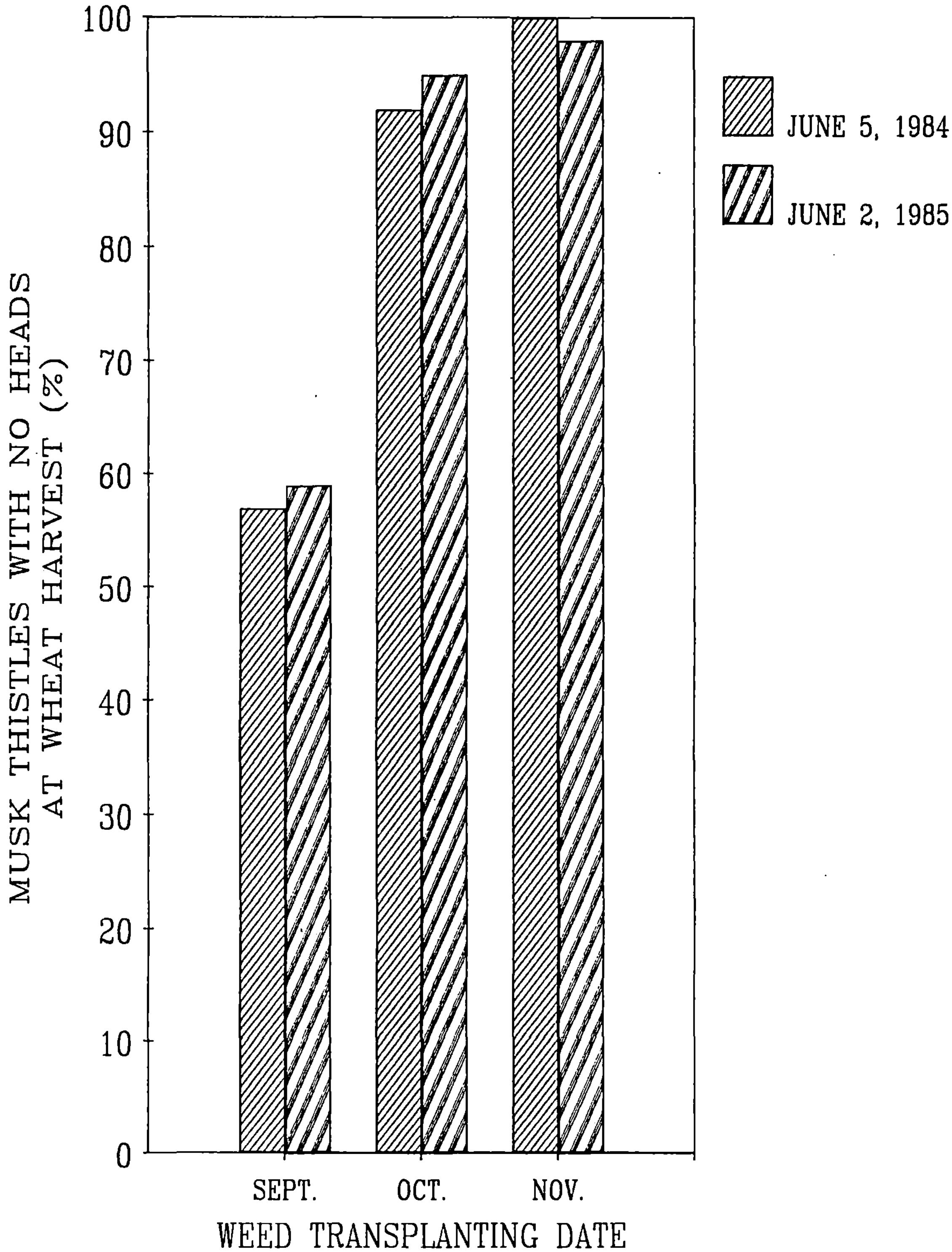

Figure 7. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on Musk Thistle Head Production

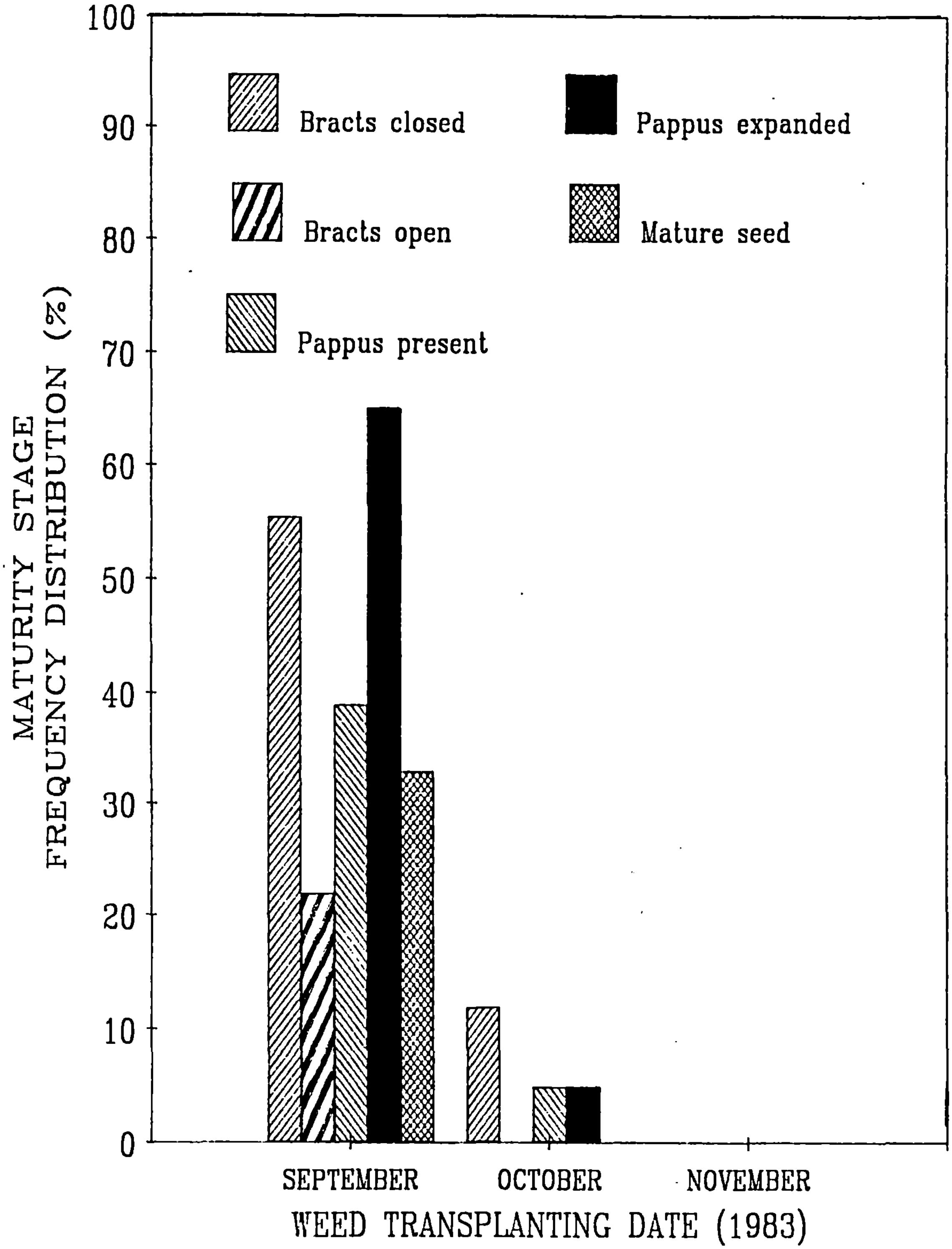

Figure 8. Effect of Transplanting Date, Averaged Over Density, on the Frequency of Musk Thistle Seed Head Maturity Stages (1983-1984)

was no difference in fresh weight, dry weight, heads/plant or the number of weevils/plant due to weed density by June 2, 1985 (Table VII). Weed density had little affect on the growth of musk thistle in either year of this research, thus there is little evidence of intraspecific competition among these densities of musk thistle growing in wheat. In 1984-1985, there again was only one significant difference in the growth of musk thistle due to weed density (Table VIII). The regression analysis provided more evidence that the interplant variability was so great, that differences in musk thistle plant height were not directly related to density, since the r^2 value obtained from the analysis was 0.22.

As in the 1983-1984 growing season, the date of weed transplanting had a major effect on musk thistle growth during the 1984-1985 growing season. Musk thistle plant height, rosette radius and leaves/plant were significantly greater in the musk thistle population transplanted on September 27, 1984 than for the musk thistles transplanted on November 3, 1984 and November 30, 1984 (Table IX). Also, musk thistles transplanted on September, 27 had significantly greater plant height, rosette radii, leaves/plant, fresh weight and dry weight than the November, 3 and November, 30 transplanted musk thistles (Table IX). There was no significant difference on June 2, 1985 between the early and late November transplanting dates.

Observations of the rosette radius and leaves/plant in the 1984-1985 growing season indicated that the variability between plants increased as the growing season progressed. At least 70% of the musk thistles transplanted on September 27, 1984 had a rosette radius of 8 to 12 cm, and a range of 8-16 leaves/plant on April 6, 1985 (Figures 9 and 10). However by June 2, 1985, 69% of the same September transplanted

TABLE VII

EFFECT OF WEED DENSITY AVERAGED OVER TRANSPLANTING DATES ON THE GROWTH AND DEVELOPMENT OF MUSK THISTLE (1984-1985)

	April 6, 1985			June 2, 1985 (Weed harvest)						
Musk Thistle Density	Plant Height	Rosette Radius	Leaves/ Plant	Plant Height	Rosette Radius	Leaves/ Plant	Fresh Wt./Plant	Dry Wt./Plant	Heads/ Plant	Weevils/ Plant[1]
(weeds/m^2)	(cm)	(cm)		(cm)	(cm)		(g)	(g)		
2	23.2	17.6	6.7	26.2	11.4	10.3	5.2	1.5	1.5	0
4	24.4	18.1	6.9	26.3	11.3	9.0	6.2	1.9	0.9	0.0
8	27.1	14.6	7.9	28.1	11.6	10.4	13.2	3.7	1.7	0.0
16	17.5	15.0	7.3	36.1	10.2	11.1	11.5	3.3	0.8	0.0
32	18.7	14.3	7.6	33.0	8.7	9.5	12.0	3.5	1.0	0.0
L.S.D. 0.05 =	5.2	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD

[1] Refers to the number of musk thistle weevils per musk thistle plant.

TABLE VIII

RELATIONSHIP OF MUSK THISTLE DENSITY TO THE GROWTH AND DEVELOPMENT OF SEPTEMBER TRANSPLANTED MUSK THISTLE (1984-1985)

Musk Thistle Density	April 6, 1985			June 2, 1985 (Weed harvest)						
	Plant Height	Rosette Radius	Leaves/ Plant	Plant Height	Rosette Radius	Leaves/ Plant	Fresh Wt./Plant	Dry Wt./Plant	Heads/ Plant	Weevils/[a] Plant
(weeds/m^2)	(cm)	(cm)		(cm)	(cm)		(g)	(g)		
2	37.7	27.9	11.5	68.6	22.6	14.2	11.5	4.2	1.5	0
4	45.9	30.8	11.9	68.2	39.3	14.0	16.3	4.1	2.7	0.1
8	54.8	24.8	12.4	110.7	33.9	17.5	38.2	10.7	4.2	0.1
16	29.1	26.0	12.2	96.5	38.9	20.6	32.2	9.6	2.6	0
32	48.8	27.1	12.7	91.8	33.7	18.8	33.5	10.3	3.0	0.1
L.S.D. 0.05 =	3.8	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD

Regression equation:[b] Plant height (April 6, 1985) $\hat{y} = 49.07 + 0.03\,x^{c}$ ($r^2 = 0.22$)

[a]Refers to the number of musk thistle weevils per musk thistle plant.

[b]Only regression equations and r^2 values with significant L.S.D. values are reported.

[c]X is equal to the number of musk thistle plants/m^2.

TABLE IX

EFFECT OF WEED TRANSPLANTING DATE AVERAGED OVER WEED DENSITY ON THE GROWTH AND DEVELOPMENT OF MUSK THISTLE (1984-1985)

Date of Musk Thistle Transplanting	April 6, 1985			June 2, 1985 (Weed harvest)						
	Plant Height	Rosette Radius	Leaves/ Plant	Plant Height	Rosette Radius	Leaves/ Plant	Fresh Wt./Plant	Dry Wt./Plant	Heads/ Plant	Weevils/ Plant[1]
	(cm)	(cm)		(cm)	(cm)		(g)	(g)		
September 27, 1984	43.2	27.3	12.1	87.1	13.2	17.0	24.4	7.7	2.8	0.07
November 3, 1984	14.8	11.9	6.0	10.0	10.9	7.6	2.1	0.1	0.0	0
November 30, 1984	8.5	8.6	3.7	13.8	7.7	6.3	0.4	0.2	0.8	0
L.S.D. 0.05 =	4.0	3.3	0.9	14.2	4.8	3.6	14.6	3.7	1.4	0.07

[1]Refers to the number of musk thistle weevils per musk thistle plant.

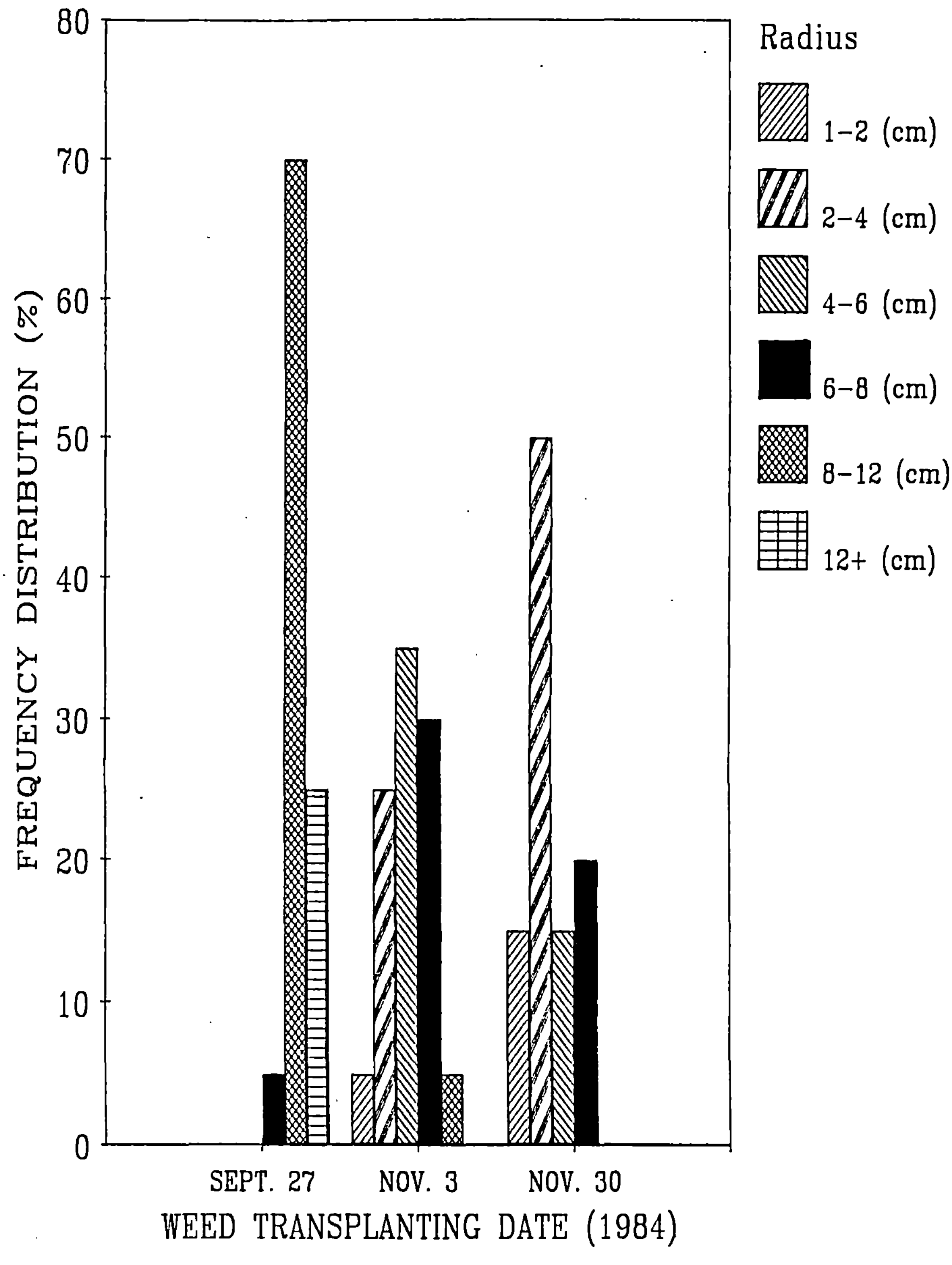

Figure 9. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on the Frequency of Occurrence of Plants With Various Ranges of Rosette Radii on April 6, 1985

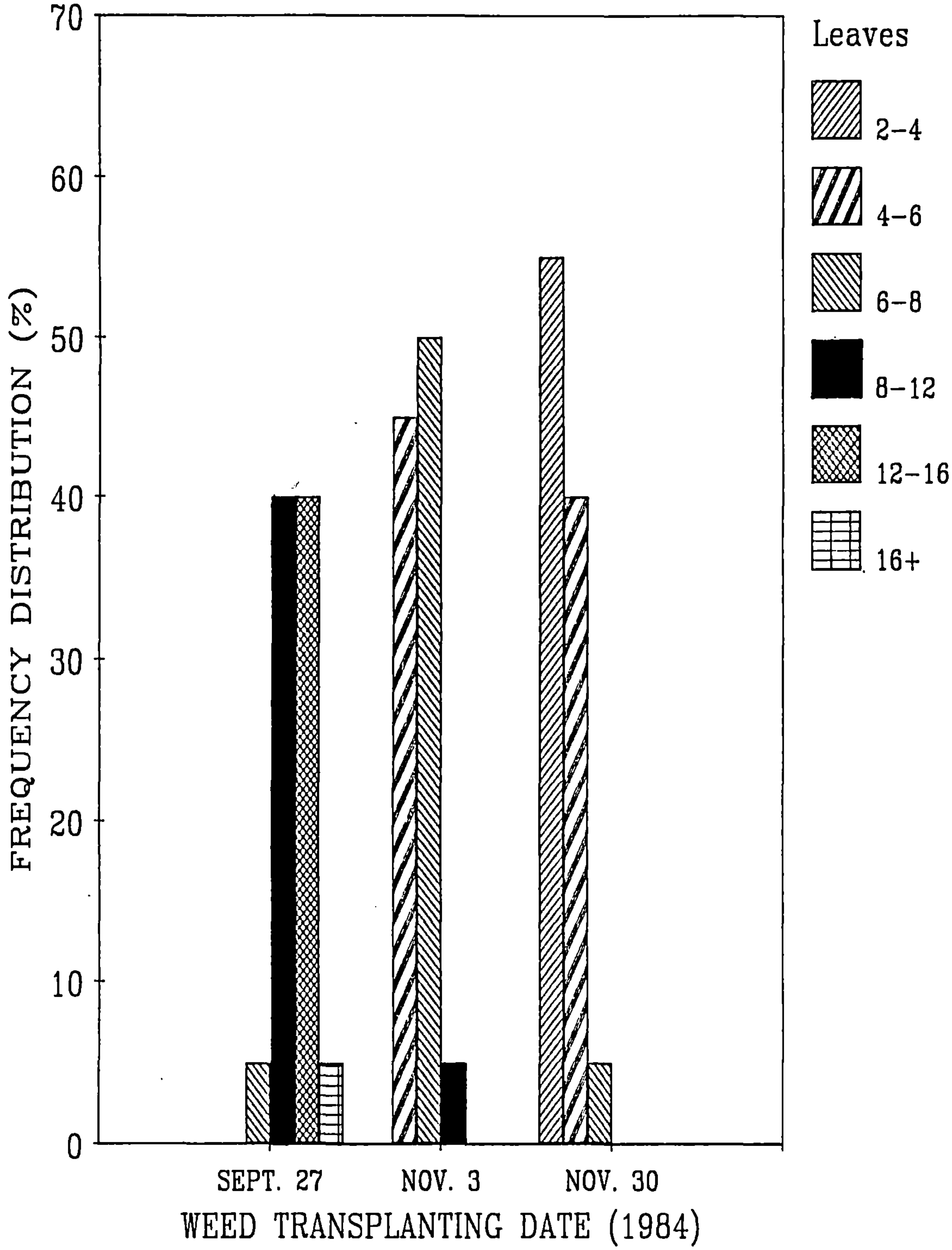

Figure 10. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on the Frequency of Occurrence of Plants With Different Numbers of Leaves on April 6, 1985

musk thistle population had a range of rosette radii from 4 to 16 cm and a range of 8-24 leaves/plant (Figures 11 and 12). The early November transplanted musk thistle population was not as variable in 1984-1985, but 95% of the late November transplanted musk thistles had from 2 to 6 leaves/plant on April 6, 1985, whereas on June 2, 1985, 95% of the late November established musk thistle population had 2 to 8 leaves/plant (Figures 10 and 12).

September transplanted musk thistles had significantly more heads/plant than the early or late November transplanted musk thistles, and there were significantly more musk thistle weevils/plant in the September transplanted musk thistles than in the early November or late November transplanted plants (Table IX). A significant weed transplanting date by relative head maturity stage interaction was present at the end of the 1984-1985 growing season for wheat. The September transplanted musk thistles had significantly more heads at each maturity stage than the early or late transplanted November musk thistles but there was no difference between the early and late November transplanting dates (Table X). As in the 1983-1984 growing season the September transplanted musk thistles had more heads in the bracts closed maturity stage than all other maturity stages and there were more heads in the pappus present maturity stage than the bracts open, pappus expanded or mature seed maturity stages (Table X).

Musk thistles transplanted at all three dates in the fall of 1984 developed various numbers of heads by wheat harvest on June 2, 1985. However, the early November and late November transplanted musk thistles did not develop heads with mature seed. Of the September transplanted musk thistle population, 59% did not develop heads. Of the early and late November transplanted musk thistles, 95 and 98% respectively failed

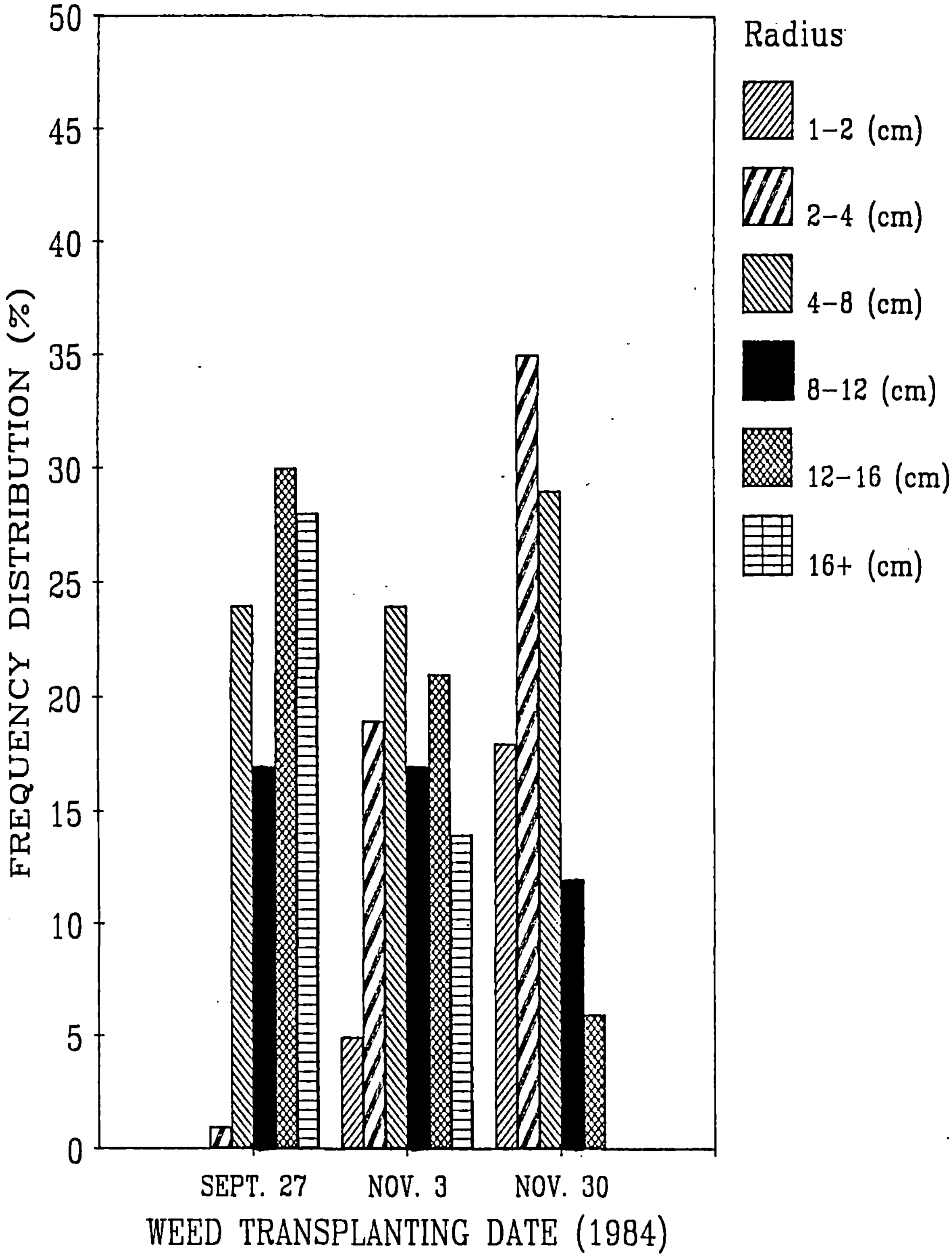

Figure 11. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on the Frequency of Occurrence of Plants With Various Ranges of Rosette Radii on June 2, 1985

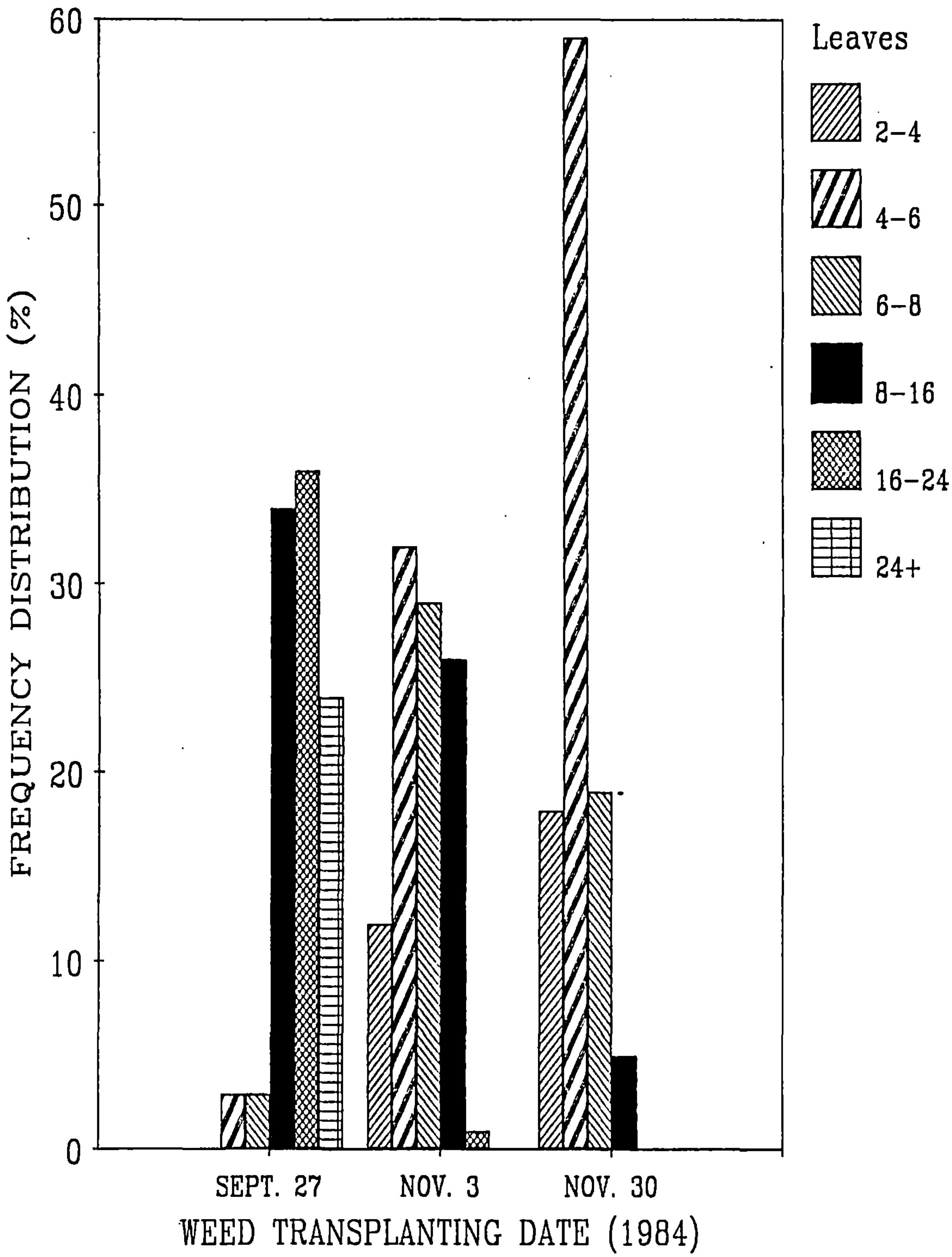

Figure 12. Effect of Musk Thistle Transplanting Date, Averaged Over Density, on the Frequency of Occurrence of Plants With Different Numbers of Leaves on June 2, 1985

TABLE X

EFFECT OF WEED TRANSPLANTING DATES ON THE RELATIVE MATURITY OF MUSK THISTLE HEADS AT WHEAT HARVEST (JUNE 2, 1985)

Musk Thistle Transplanting Date	Head Maturity[1]				
	Bracts Closed	Bracts Open	Pappus Present	Pappus Expanded	Mature Seed
	Number of heads per plant at each maturity stage				
September 27, 1984	0.87	0.05	0.66	0.28	0.13
November 3, 1984	0.04	0.01	0.01	0	0
November 30, 1984	0.03	0	0.03	0.03	0.03

L.S.D. 0.05 for comparing maturity stage by transplanting date interaction = 0.12

[1] Musk thistle maturity stages are illustrated in Figure 2.

to begin head development (Figure 7). At least 20% of the September transplanted musk thistles developed heads with the pappus expanded or with mature seeds by June 2, 1985 (Figure 13).

Measurement of rosette radii during 1983-1984 revealed that approximately 45% of the musk thistle rosette growth occurred prior to April 5, for the September, October and November transplanted musk thistles (Figures 14). Also, nearly 70% of the leaves/plant were produced by April 5, 1983 for the musk thistles transplanted in September, October and November (Figure 15). Approximately 30 days after the September musk thistles were transplanted the growth of the musk thistles decreased (Figures 14 and 15). This reduction in growth occurred after the night temperature declined to 37 C or less for two consecutive days. However, head development was initiated by April 5, 1983 for the September and October transplanted musk thistle, but head development was not recorded until June 5, 1985 for the November transplanted musk thistles (Figures 16 and 17).

No weed transplanting date by weed density interaction was present in the clean grain yield data (Table XI). Therefore the data is averaged over weed transplanting dates. Sixteen musk thistle plants/m^2 significantly reduced the grain yield of TAM W101 wheat in 1983-1984, while grain yields were not reduced by any density of musk thistle in 1984-1985 (Table XI). Thus it appeared that musk thistle is not a strong competitor with winter wheat.

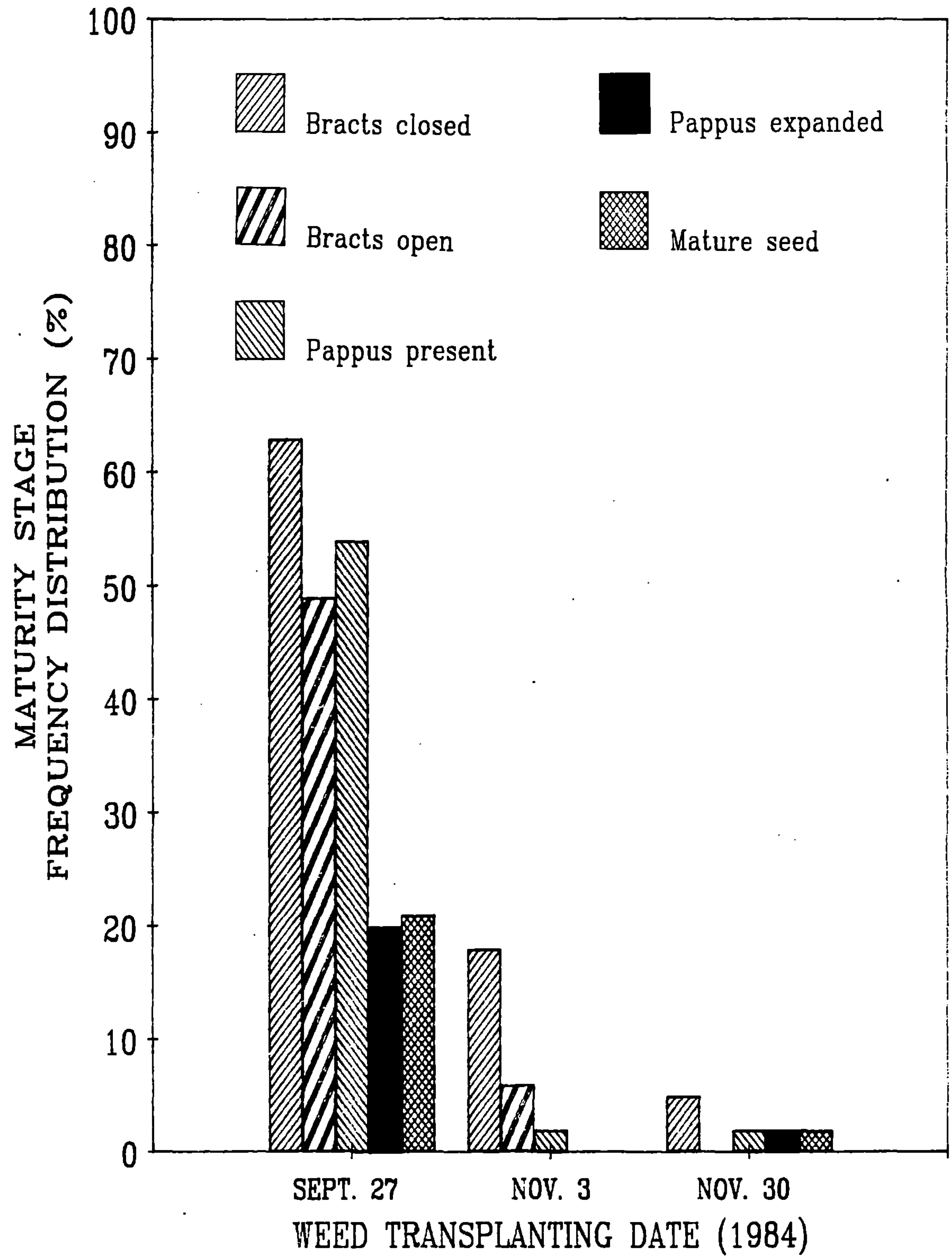

Figure 13. Effect of Transplanting Date, Averaged Over Density, on the Frequency of Musk Thistle Seed Head Maturity Stages (1984-1985)

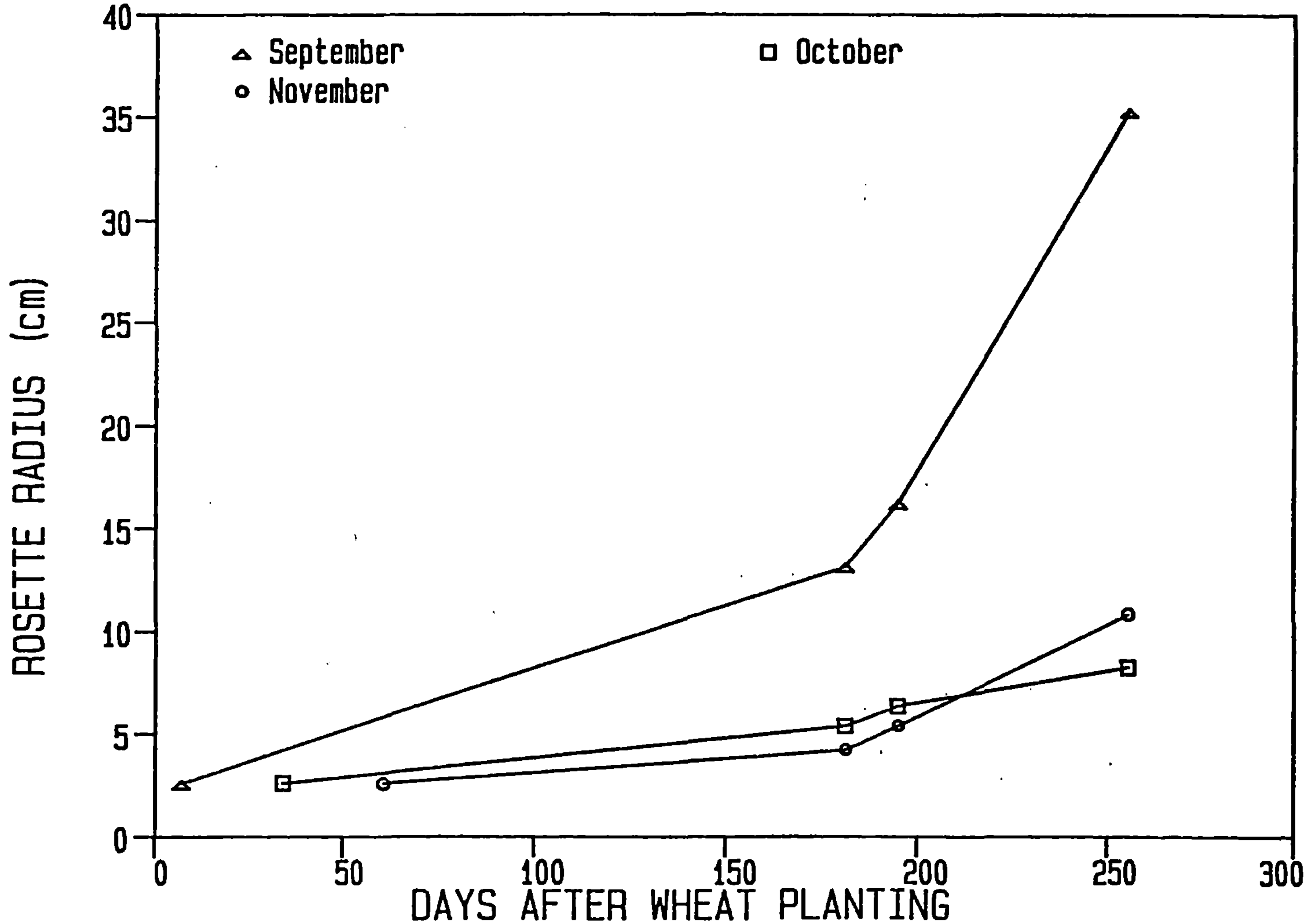

Figure 14. Effect of Transplanting Date on the Rosette Radius of Musk Thistle From Wheat Planting to Wheat Harvest (1983-1984)

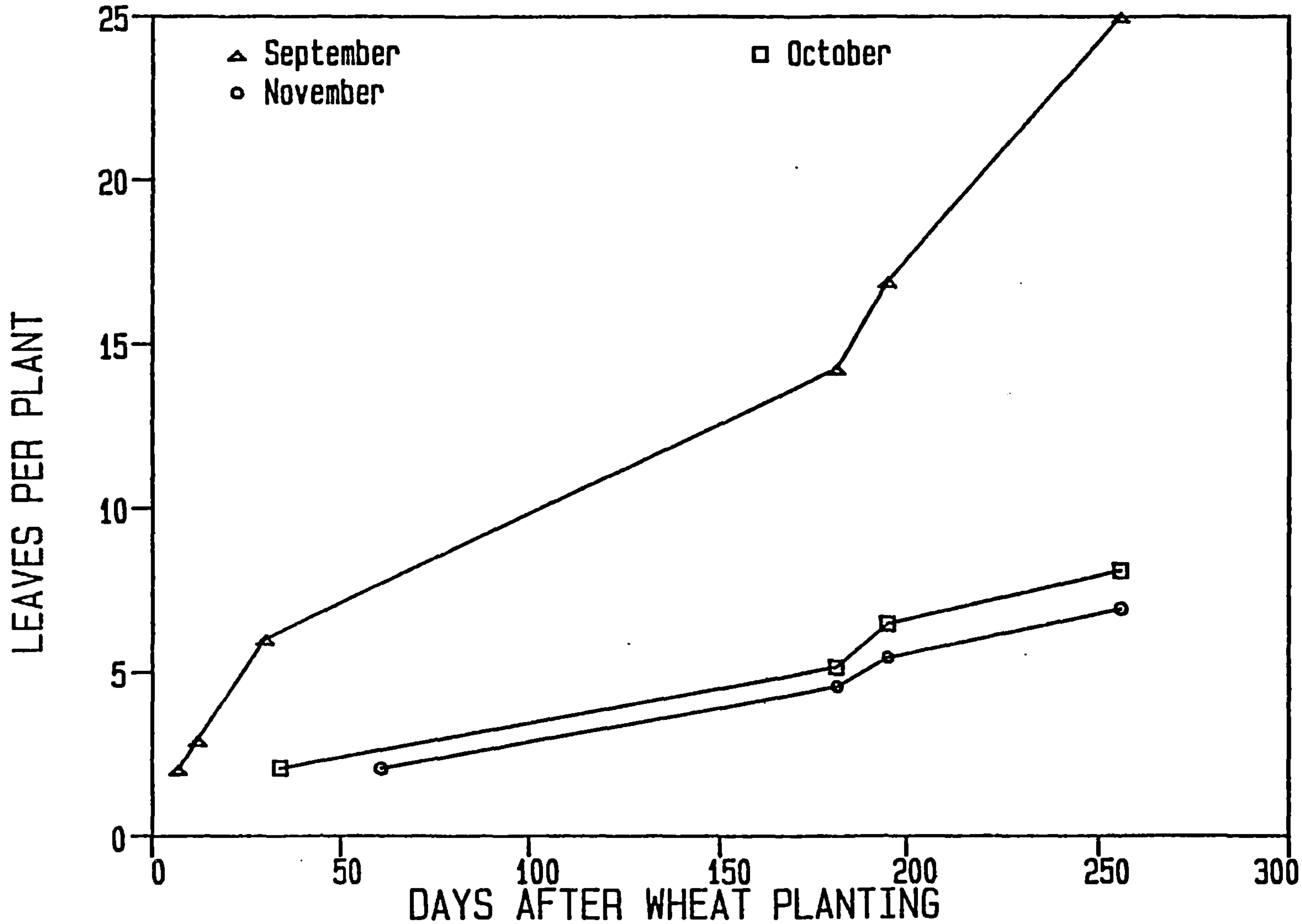

Figure 15. Effect of Transplanting Date on Musk Thistle Leaves/Plant From Wheat Planting to Wheat Harvest (1983-1984)

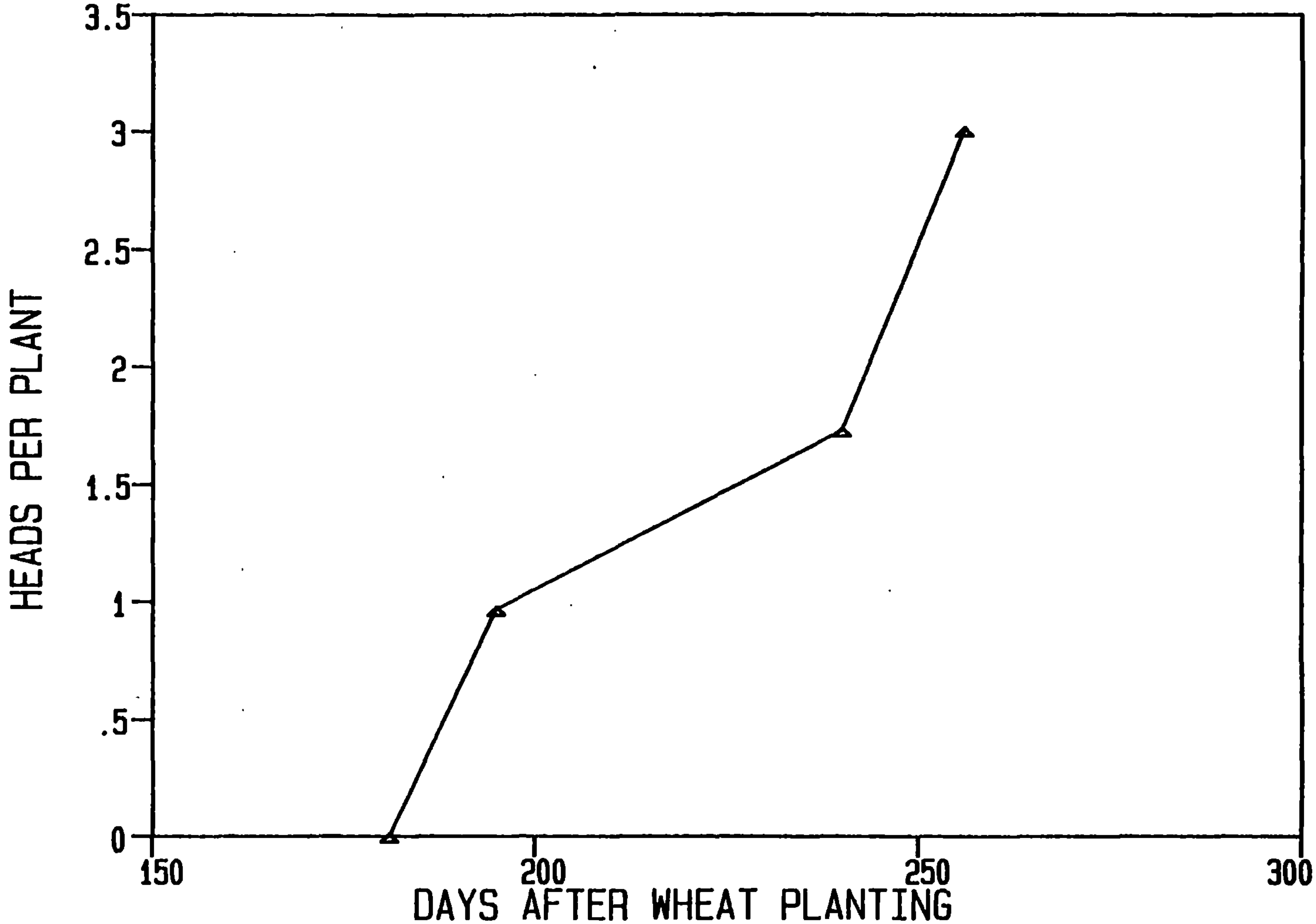

Figure 16. Mean Number of Seed Heads Present at Various Times in the Spring on September Transplanted Musk Thistles (1983-1984)

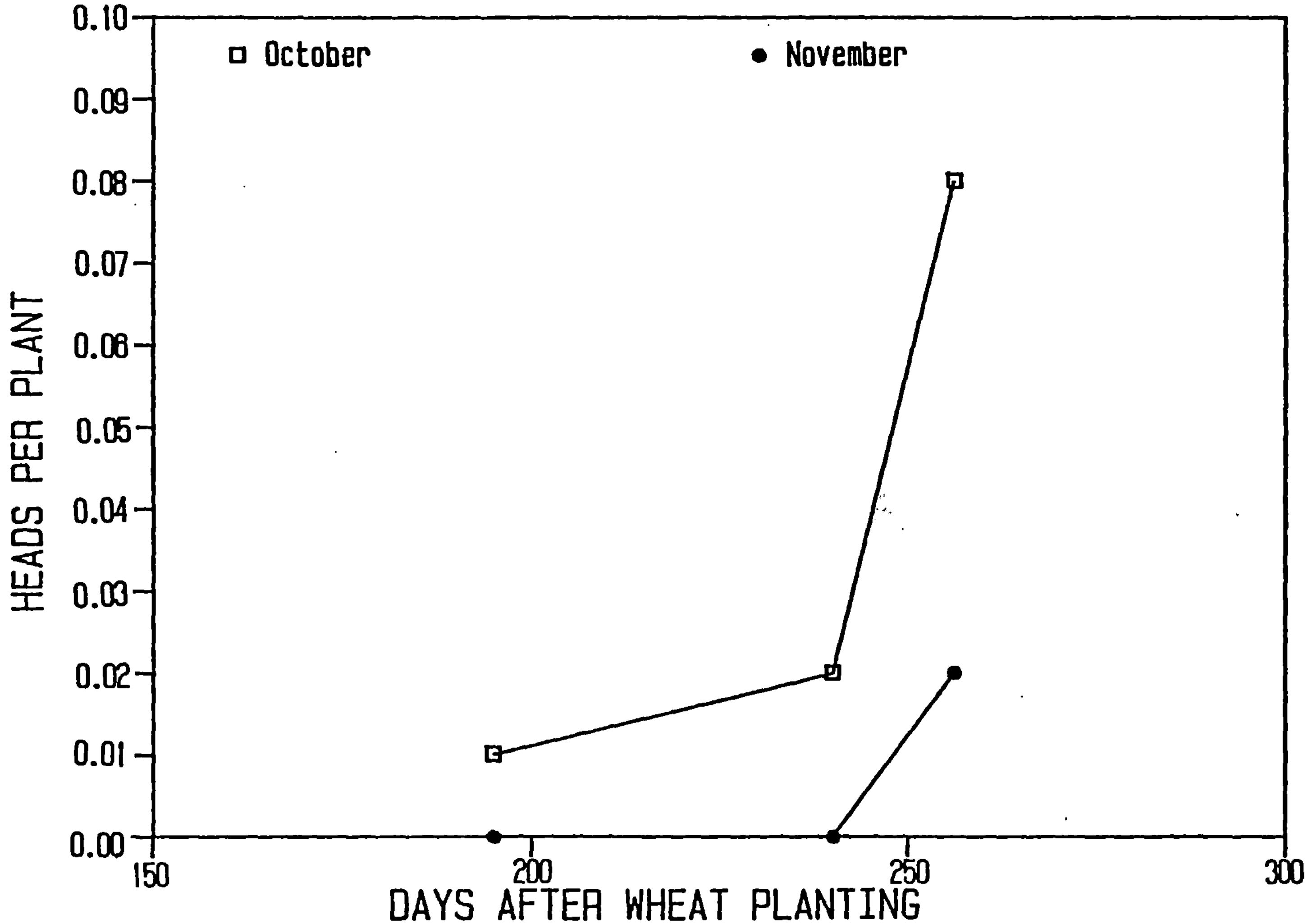

Figure 17. Mean Number of Seed Heads Present at Various Times in the Spring on October and November Transplanted Musk Thistles (1983-1984)

TABLE XI

EFFECT OF MUSK THISTLE ON THE YIELD OF WINTER WHEAT

Musk Thistle Density	Date of Wheat Harvest							
	June 5, 1984				June 2, 1985			
	(Date of Musk Thistle Transplanting)							
	Sept. 29, 1983	Oct. 26, 1983	Nov. 22, 1983	Mean	Sept. 27, 1984	Nov. 3, 1984	Nov. 30, 1984	Mean
(weeds/m^2)		(Kg/ha)				(Kg/ha)		
0	3684	4140	3916	3893	3258	3665	4064	3662
2	3724	3779	3532	3678	3961	3504	3249	3571
4	4448	4525	4132	4368	3502	3590	3777	3623
8	4709	4617	3419	4248	3647	3956	3690	3764
16	3311	3135	3375	3274	3162	3849	3434	3482
32	3015	3863	4028	3635	3420	3891	4049	3787
L.S.D. 0.05[1] =		[NSD]		582		[NSD]		NSD

[1] L.S.D.'s in [ ], are used to compare the date of weed transplanting by weed density interaction, the other L.S.D. values are used to compare weed density means averaged over weed transplanting dates.

Effect of Corn Gromwell Density and Transplanting Date in its Growth and Development in and Competition with Winter Wheat

There was no significant effect of corn gromwell densities varying from 2 to 32 plants/m^2 on leaves/plant, leaf length, plant height, basal stems/plant, fresh weight or dry weight of the corn gromwell plants on March 10, 1984, April 9, 1984 and/or June 5, 1984 (Table XII). Also there was no difference in flowers/plant or calyxes/plant on April 9, 1984 and June 5, 1984. Thus, up to a density of 32 plants/m^2, there was no indication of intraspecific competition among corn gromwell plants growing in winter wheat. The relationship between weed density and corn gromwell growth was evaluated just as with musk thistle. Regression analysis of the 1983-1984 corn gromwell growth data revealed that the leaves/plant, leaf length and plant height of corn gromwell were not affected by density when measured on March 10, 1984. However on April 9, plant height of the 8, 16 and 32/m^2 densities were greater than the 2 and 4/m^2 densities. Again the r^2 value of 0.06 for plant height indicates that the regression analysis is not describing the variability between plants (Table XIII). From April 9, to June 5, 1984 the basal stems/plant, flowers/plant, plant height , fresh weight, dry weight and calyxes/plant were not affected by density.

As with musk thistle, there were no weed density by transplanting date interactions in the data and transplanting date was the major factor affecting growth and development of corn gromwell. Observations in early spring 1984, revealed a significant decrease in plant height, leaf length and leaves/plant on plants transplanted in October compared to September transplanted plants (Table XIV). Delaying transplanting

TABLE XII

EFFECT OF WEED DENSITY AVERAGED OVER TRANSPLANTING DATES ON THE GROWTH AND DEVELOPMENT OF CORN GROMWELL (1983-1984)

Corn Gromwell Density	March 10, 1984			April 9, 1984			June 5, 1984 (Weed Harvest)				
	Leaves/ Plant	Leaf Length	Plant Height	Plant Height	Basal Stems/ Plant	Flowers/ Plant	Plant Height	Basal Stems/ Plant	Calyxes/ Plant	Fresh Wt./ Plant	Dry Wt./ Plant
(weeds/m^2)		(cm)	(cm)	(cm)			(cm)			(g)	(g)
2	21.0	11.2	16.5	44.5	0.5	2.1	41.6	0.2	20.7	18.4	8.4
4	22.4	11.7	17.2	49.2	0.9	2.1	44.5	0.7	21.0	18.3	9.2
8	25.2	13.4	17.5	52.9	0.7	2.3	43.6	0.5	81.3	18.0	14.5
16	31.6	11.7	16.8	51.0	1.0	2.7	44.9	1.0	44.3	22.0	15.1
32	31.7	13.3	19.6	52.0	1.0	2.7	43.3	1.0	36.0	23.7	11.8
L.S.D. 0.05 =	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD

TABLE XIII

RELATIONSHIP OF CORN GROMWELL DENSITY TO THE GROWTH AND DEVELOPMENT OF SEPTEMBER TRANSPLANTED CORN GROMWELL (1983-1984)

Corn Gromwell Density	March 10, 1984			April 9, 1984			June 5, 1984 (Weed Harvest)				
	Leaves/ Plant	Leaf Length	Plant Height	Plant Height	Basal Stems/ Plant	Flowers/ Plant	Plant Height	Basal Stems/ Plant	Calyxes/ Plant	Fresh Wt./ Plant	Dry Wt./ Plant
(weeds/m^2)		(cm)	(cm)	(cm)			(cm)			(g)	(g)
2	42.7	14.1	26.3	61.0	1.6	4.5	50.1	0.6	40.7	27.6	16.6
4	40.9	13.7	23.2	60.0	2.7	4.5	52.7	2.1	36.6	27.3	16.1
8	48.7	16.6	24.9	67.3	2.2	4.9	56.0	1.7	210.6	36.1	32.2
16	67.1	14.0	24.4	68.0	2.9	5.6	58.0	2.9	100.2	36.0	35.1
32	66.1	17.4	27.4	72.8	3.1	5.9	57.2	3.0	88.8	44.1	25.9
L.S.D. 0.05 =	NSD	NSD	NSD	5.8	NSD	NSD	NSD	NSD	NSD	NSD	NSD

Regression equation[a] : Plant height (April 9, 1984) $\hat{y} = 61.6 + 0.3305 x^b$ ($r^2 = 0.06$)

[a]Only regression equation and r^2 value with significant L.S.D. values are given.

[b]X is equal to the numbers of corn gromwellplants/m^2.

TABLE XIV

EFFECT OF WEED TRANSPLANTING DATE ON THE GROWTH AND DEVELOPMENT OF CORN GROMWELL (1983-1984)

Date of Corn Gromwell Transplanting	March 10, 1984			April 9, 1984			June 2, 1984 (Weed Harvest)				
	Leaves/ Plant	Leaf Length	Plant Height	Plant Height	Basal Stems/ Plant	Flowers/ Plant	Plant Height	Basal Stems/ Plant	Calyxes/ Plant	Fresh Wt./ Plant	Dry Wt./ Plant
		(cm)	(cm)	(cm)			(cm)			(g)	(g)
September 29, 1983	53.0	15.1	25.2	65.8	2.5	5.0	54.5	2.0	98.9	36.8	26.1
October 26, 1983	16.0	14.6	16.3	52.5	0	4.4	44.0	0	16.9	16.7	7.4
November 22, 1983	10.1	7.1	11.1	31.4	0	0.4	32.3	0	6.3	10.2	2.4
L.S.D. 0.05 =	5.4	2.1	2.0	5.6	0.5	0.9	5.2	0.6	7.2	9.4	7.9

until November further decreased the vegetative growth present in March and April, and the numbers of reproductive structures present at wheat harvest.

Since transplanting date had a major effect on corn gromwell plant height and basal stems/plant, and there was a lot of variation within the population, the data was categorized to more clearly understand the development of different proportions of the population. Observation of the variation between plants on April 9, 1984 revealed that 86% of the September transplanted population had a plant height of 60 to over 80 cm, whereas in the October transplanted plants 80% of the population had plant heights that ranged from 40 to 80 cm. Eighty-four percent of the November transplanted corn gromwell had plant heights that varied from 20 to 60 cm (Figure 18). This same trend occurred in the plant height data obtained on June 5, 1984 (Figure 19). At least 94% of the October and November transplanted corn gromwell populations did not develop any basal stems by April 9, 1984 and 99% of these populations did not have at least one basal stem/plant on June 5, 1984 (Figures 20 and 21). Over the same period, September transplanted plants varied in their number of basal stems/plant from 0 to over 12.

In 1984-1985 there again appeared to be very little effect of corn gromwell density on its growth in wheat. Weed density had no affect on plant height, basal stems/plant, fresh weight or dry weight on April 13, 1985 and/or June 2, 1985. Also, the number of flowers/plant on April 13 and calyxes/plant on June 2 were not affected by density (Table XV). However when the growth of September transplanted corn gromwell was regressed against density, the basal stems/plant and fresh weight/plant were significantly affected by density on June, 2 (Table XVI). Corn gromwell at 32 plants/m^2 had developed more basal stems/plant than the

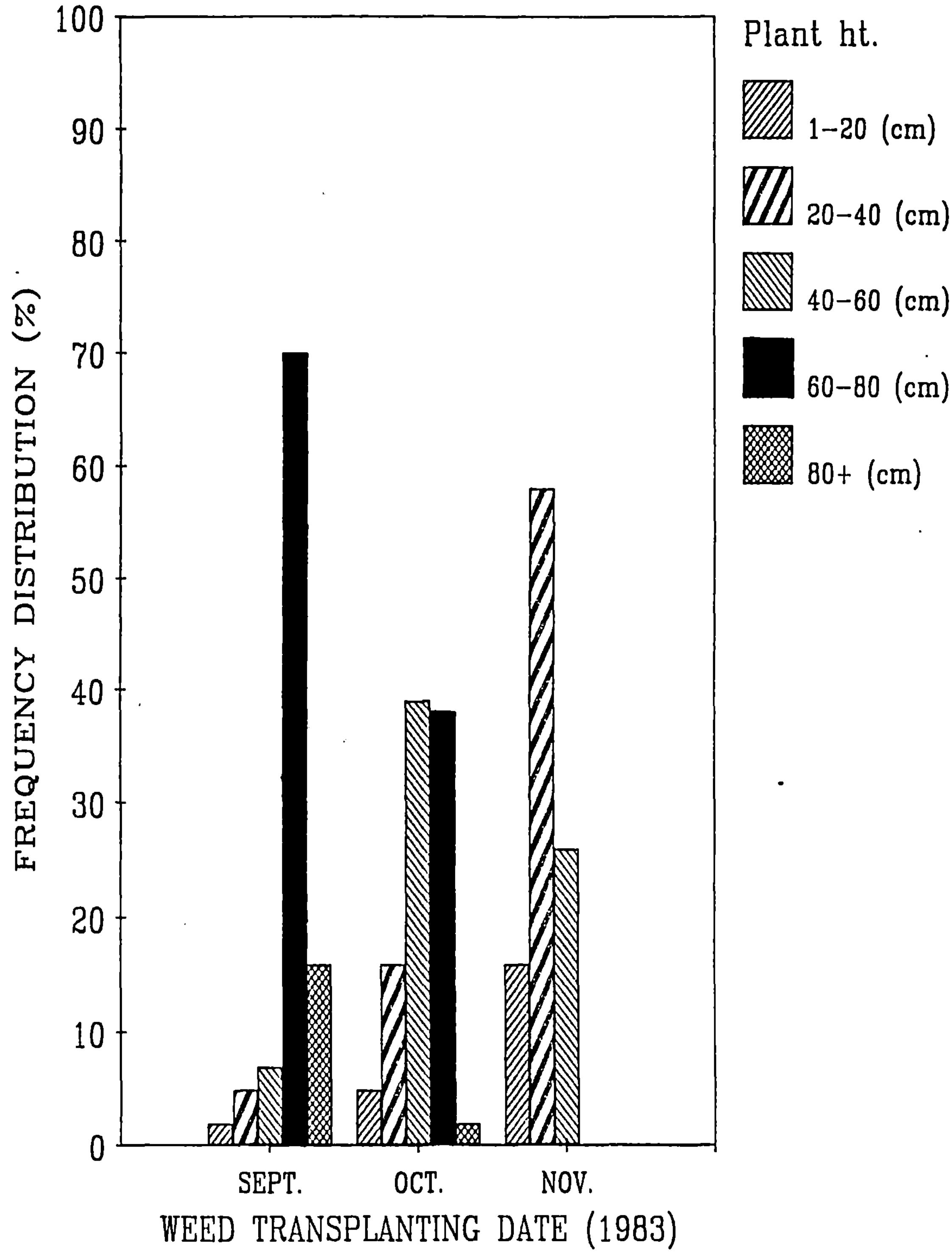

Figure 18. Effect of Corn Gromwell Transplanting Date, Averaged Over Density, on the Variation in Height of Corn Gromwell Plants on April 9, 1984

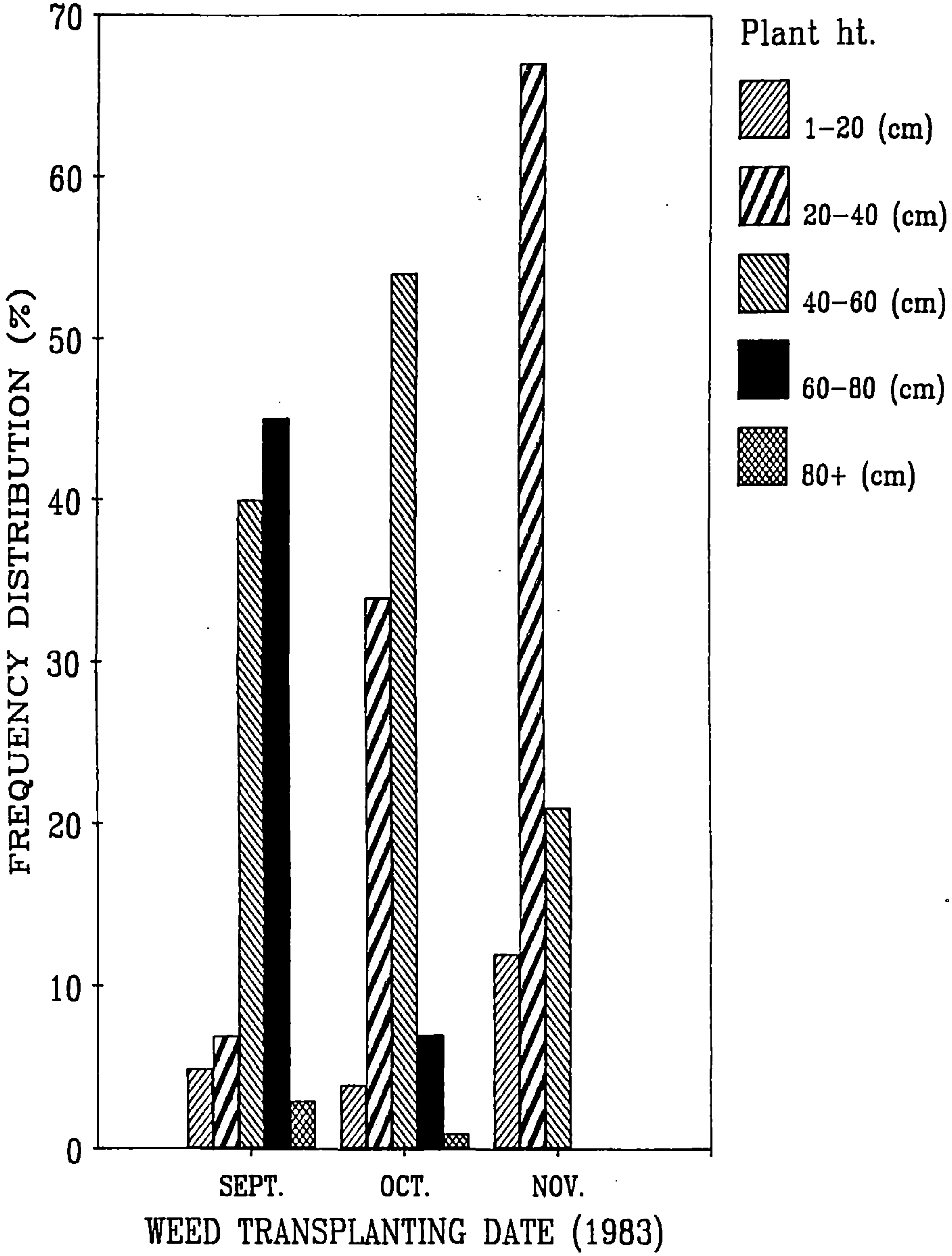

Figure 19. Effect of Corn Gromwell Transplanting Date, Averaged Over Density, on the Variation in Height of Corn Gromwell Plants on June 5, 1984

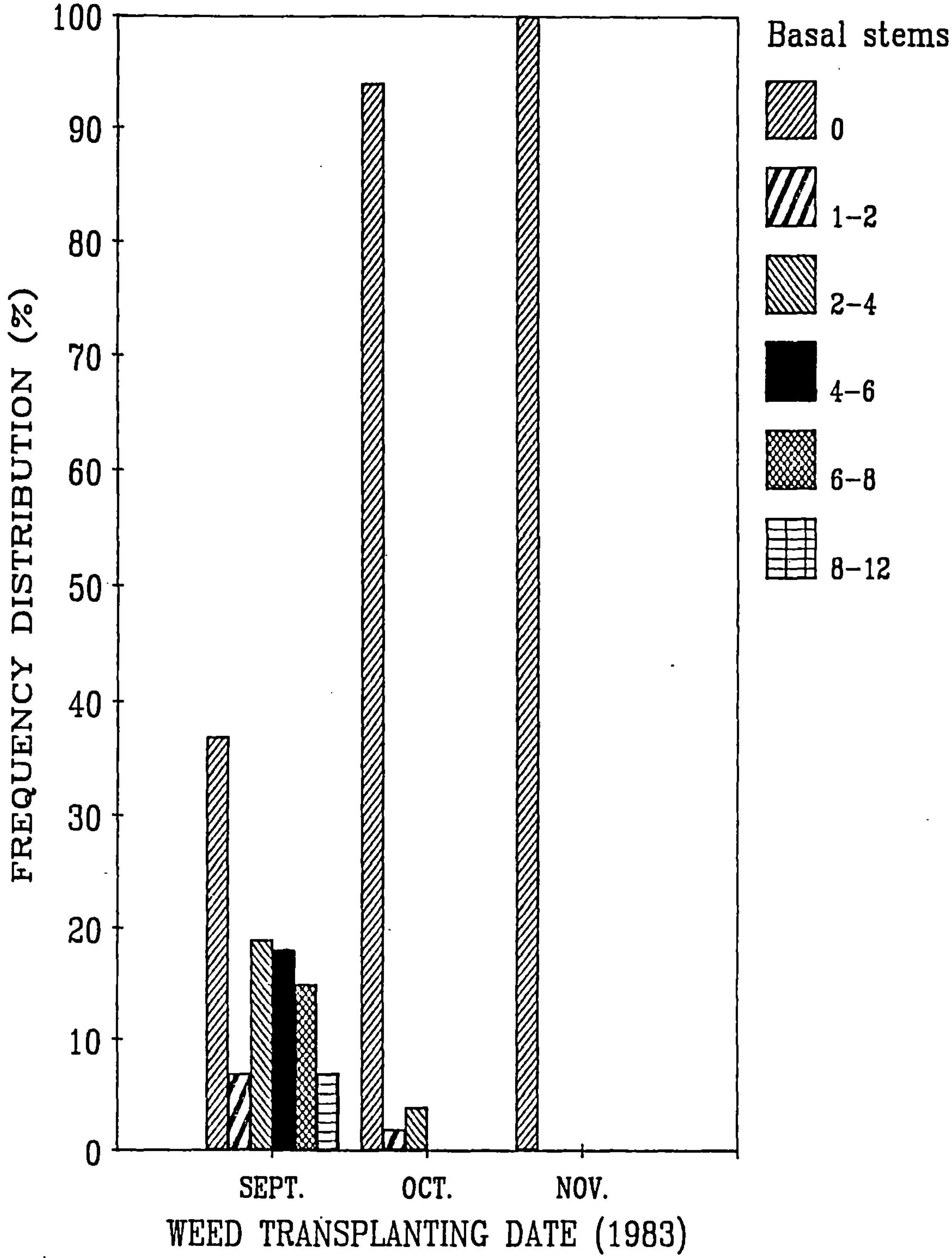

Figure 20. Effect of Corn Gromwell Transplanting Date, Averaged Over Density, on the Frequency of Corn Gromwell Plants With Various Numbers of Basal Stems/Plant on April 9, 1984

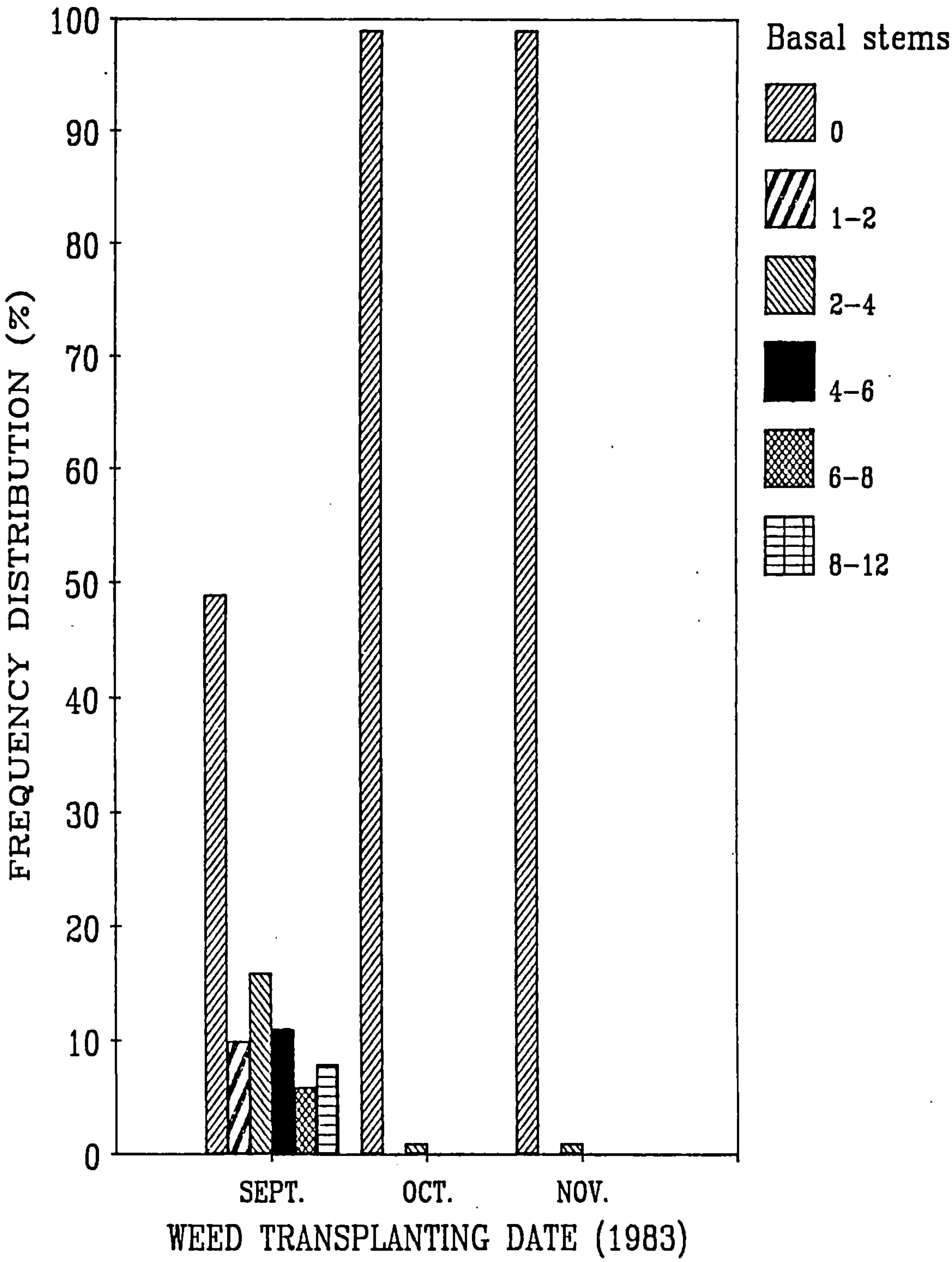

Figure 21. Effect of Corn Gromwell Transplanting Date, Averaged Over Density, on the Frequency of Corn Gromwell Plants With Various Numbers of Basal Stems/Plant on June 5, 1984

TABLE XV

EFFECT OF WEED DENSITY AVERAGED OVER TRANSPLANTING DATES ON THE GROWTH AND DEVELOPMENT OF CORN GROMWELL (1984-1985)

Corn Gromwell Density	April 13, 1985			June 2, 1985 (Weed Harvest)				
	Plant Height	Basal Stems/Plant	Flowers/ Plant	Plant Height	Basal Stems/Plant	Calyxes/ Plant	Fresh Wt./Plant	Dry Wt./Plant
(weeds/m^2)	(cm)			(cm)			(g)	(g)
2	18.2	6.7	0.6	25.9	1.8	2.4	23.2	4.3
4	21.8	5.4	0.7	29.5	1.6	4.5	24.8	7.4
8	17.9	4.6	0.7	23.7	2.8	4.0	26.6	8.2
16	18.5	6.1	0.7	23.8	5.4	3.2	27.0	6.5
32	18.4	4.7	0.7	26.7	4.2	2.8	25.2	5.4
L.S.D. 0.05 =	NSD	NSD	NSD	NSD	NSD	NSD	NSD	NSD

TABLE XVI

RELATIONSHIP OF CORN GROMWELL DENSITY TO THE GROWTH AND DEVELOPMENT OF SEPTEMBER TRANSPLANTED CORN GROMWELL PLANTS (1984-1985)

Corn Gromwell Density	April 13, 1985			June 2, 1985 (Weed harvest)				
	Plant Height	Basal Stems/ Plant	Flowers/ Plant	Plant Height	Basal Stems/ Plant	Calyxes/ Plant	Fresh wt./ Plant	Dry wt./ Plant
(weeds/m^2)	(cm)	(cm)		(cm)			(g)	(g)
2	25.0	11.2	0.9	21.4	2.6	4.8	25.8	6.4
4	29.1	12.0	1.0	27.1	2.1	10.4	34.3	16.2
8	26.1	10.1	1.1	18.6	3.2	8.6	33.6	16.3
16	22.6	11.4	1.0	18.1	6.0	7.2	33.5	13.7
32	24.6	10.0	1.7	20.8	10.1	6.7	32.3	12.1
L.S.D. 0.05 =	NSD	NSD	NSD	NSD	5.2	NSD	3.1	NSD

Regression equation[a]: Basal stems/plant (June 2, 1985) $\hat{y} = 0.42 + 0.26\ x^b$ ($r^2 = 0.31$)

Fresh wt./plant (June 2, 1985) $\hat{y} = 30.55 + 0.48\ x - 0.01\ x^2$ ($r^2 = 0.06$)

[a]Only regression equations and r^2 values with significant L.S.D. values are given.

[b]X is equal to the number of corn gromwellplants/m^2.

densities of 2, 4 or $8/m^2$. As with previous regression analysis the r^2 values for basal stems/plant and fresh weight/plant were 0.31 and 0.06 respectively. These results again indicate substantial variability among the corn gromwell density.

As in 1983-1984, transplanting date had a significant affect on the growth and reproduction of corn gromwell in 1984-1985. In April, 1985 the plant height, basal stem/plant and flowers/plant of the late September transplanted corn gromwell were significantly greater than the early November transplanted plants (Table XVII). By early June, the differences in plant height and reproduction were even more pronounced. Delaying transplanting from November 3 to November 30, further decreased plant height in April, but some plants were still able to bloom by mid-April.

A grouping of plant height by transplanting dates was apparent in the April 13, 1985 data. Eighty-five percent of the September transplanted corn gromwell plants were 40 to over 80 cm tall, whereas 62% of early November transplanted plants were less than 60 cm tall. In contrast, none of the late November transplanted plants were over 60 cm high (Figure 22). This same trend was apparent on June 2, 1985 for the early November and late November transplanting dates, however the September transplanted corn gromwell apparently had a reduction in plant height due to plant maturity and post-harvest drying procedures (Figure 23).

A grouping of basal stems/plant also was apparent in 1985 for all three transplanting dates on both April 13 and June 2 (Figure 24 and 25). Eighty-eight percent of the September transplanted corn gromwell had at least 8 basal stems/plant on April 13. However, a reduction in the number of basal stems/plant occurred by early June which was

TABLE XVII

EFFECT OF WEED TRANSPLANTING DATE AVERAGED OVER WEED DENSITY ON THE GROWTH AND DEVELOPMENT OF CORN GROMWELL (1984-1985)

Date of Corn Gromwell Transplanting	April 13, 1985			June 2, 1985 (Weed harvest)				
	Plant Height	Basal Stems/Plant	Flowers/ Plant	Plant Height	Basal Stems/Plant	Calyxes/ Plant	Fresh Wt./Plant	Dry Wt./Plant
	(cm)			(cm)			(g)	(g)
September 27, 1984	25.5	10.9	1.0	53.3	5.2	7.6	31.9	12.9
November 3, 1984	21.6	3.0	0.8	16.6	4.1	2.4	28.2	5.8
November 30, 1984	9.8	2.7	0.3	6.9	3.1	0.1	15.9	0.4
L.S.D. 0.05 =	3.3	1.0	0.1	6.5	1.7	1.2	2.5	2.7

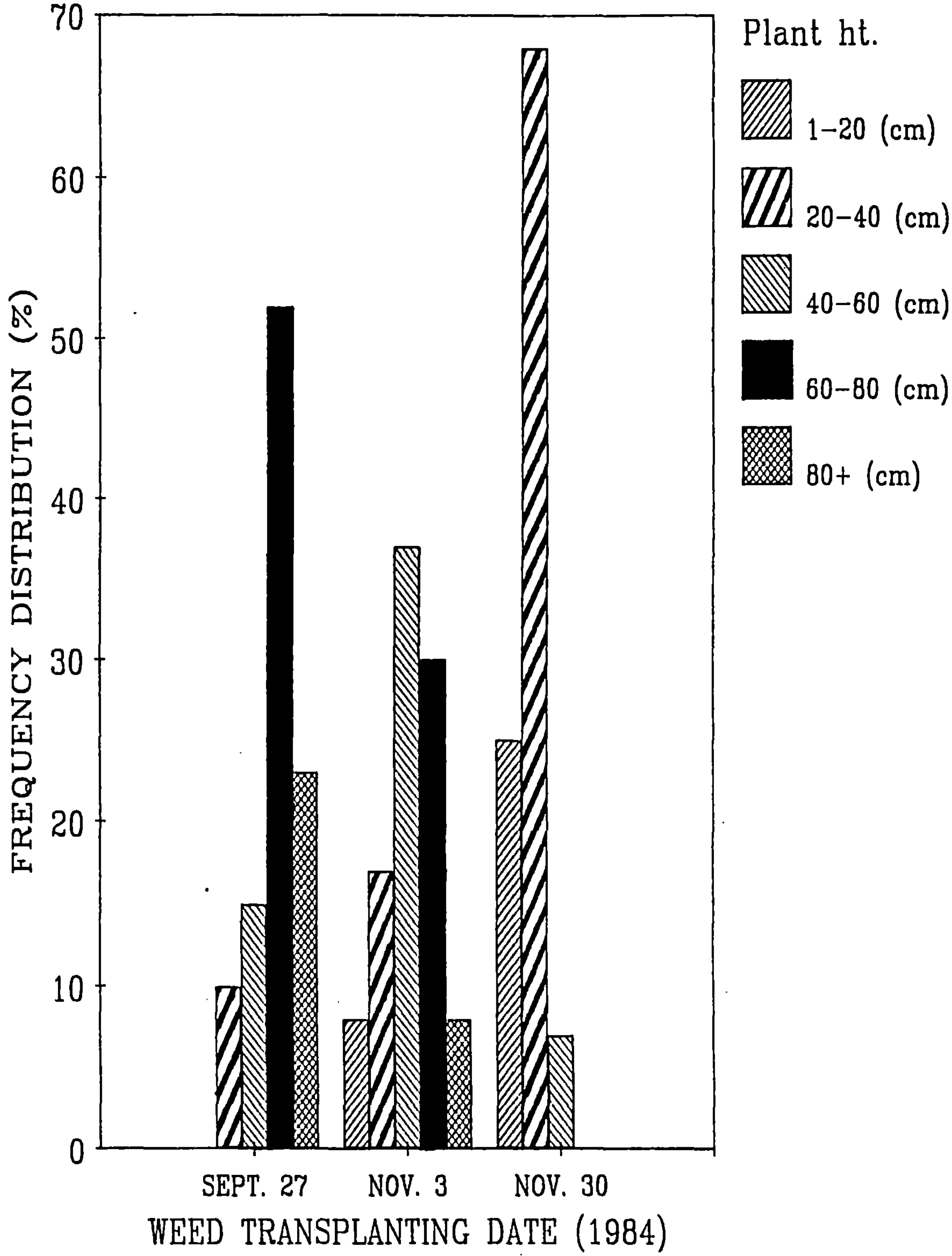

Figure 22. Effect of Corn Gromwell Transplanting Date, Averaged Over Density, on the Variation in Height of Corn Gromwell Plants on April 13, 1985

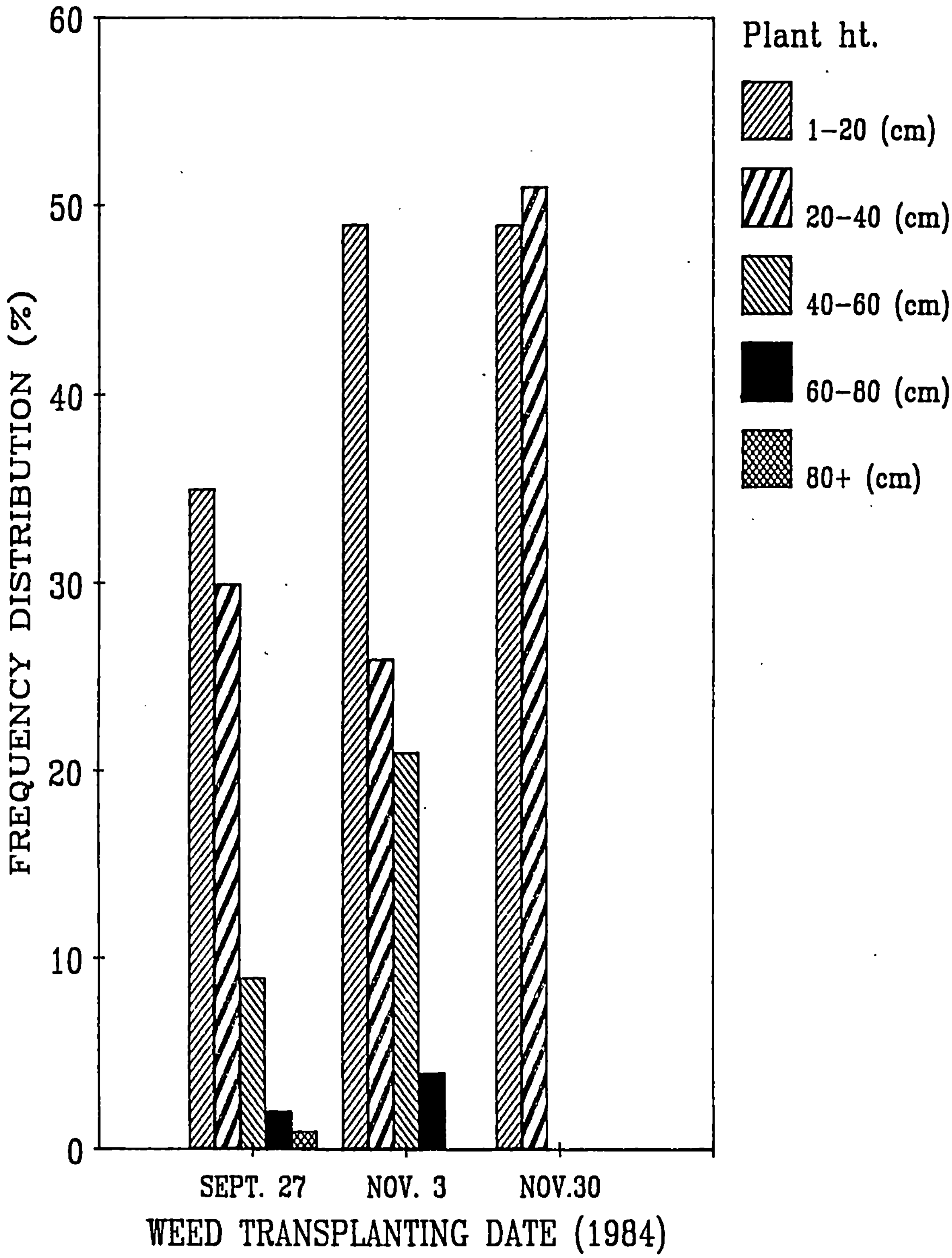

Figure 23. Effect of Corn Gromwell Transplanting Date, Averaged Over Density, on the Variation in Height of Corn Gromwell Plants on June 2, 1985

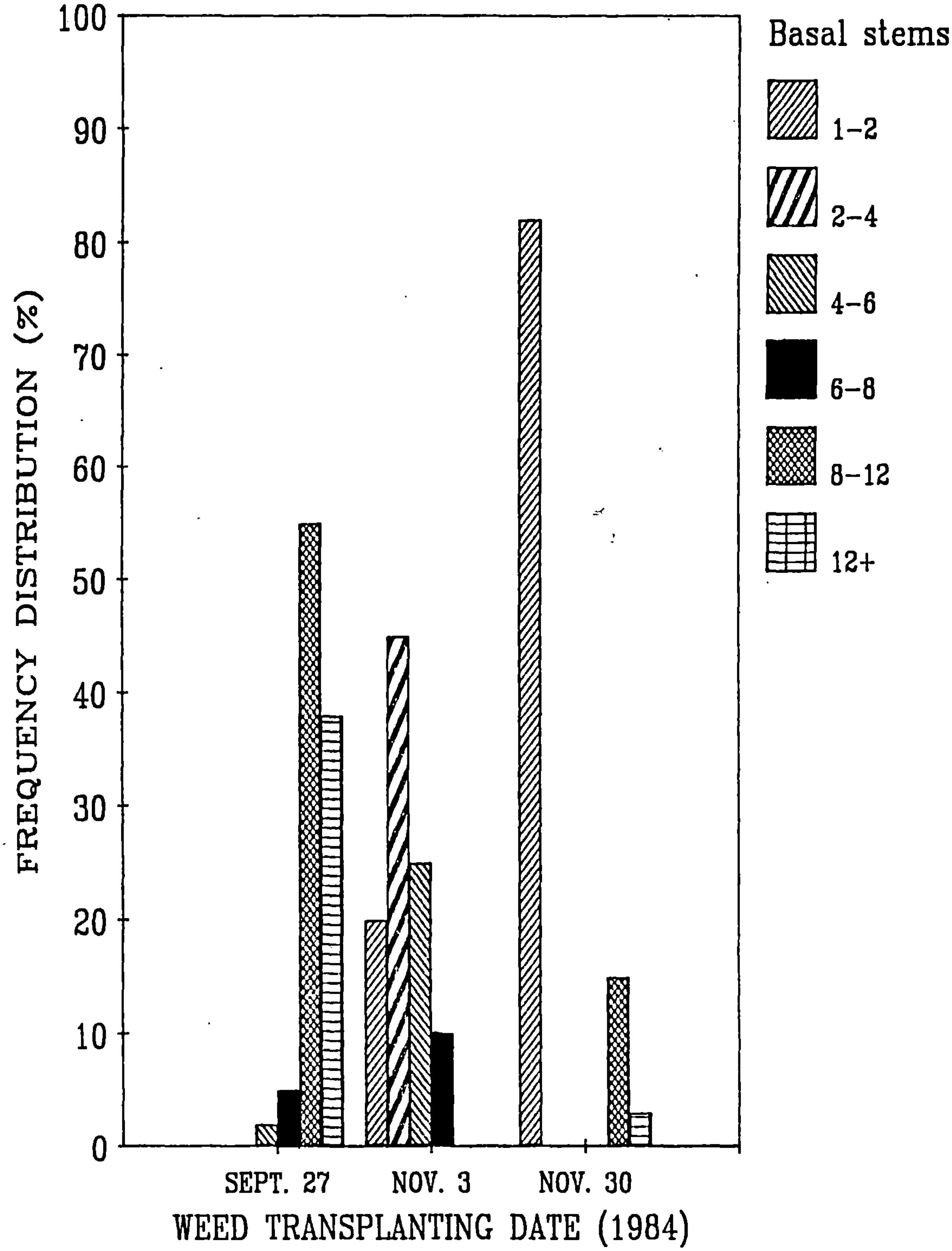

Figure 24. Effect of Corn Gromwell Transplanting Date, Averaged Over Density, on the Frequency of Corn Gromwell Plants With Various Numbers of Basal Stems/Plant on April 13, 1985

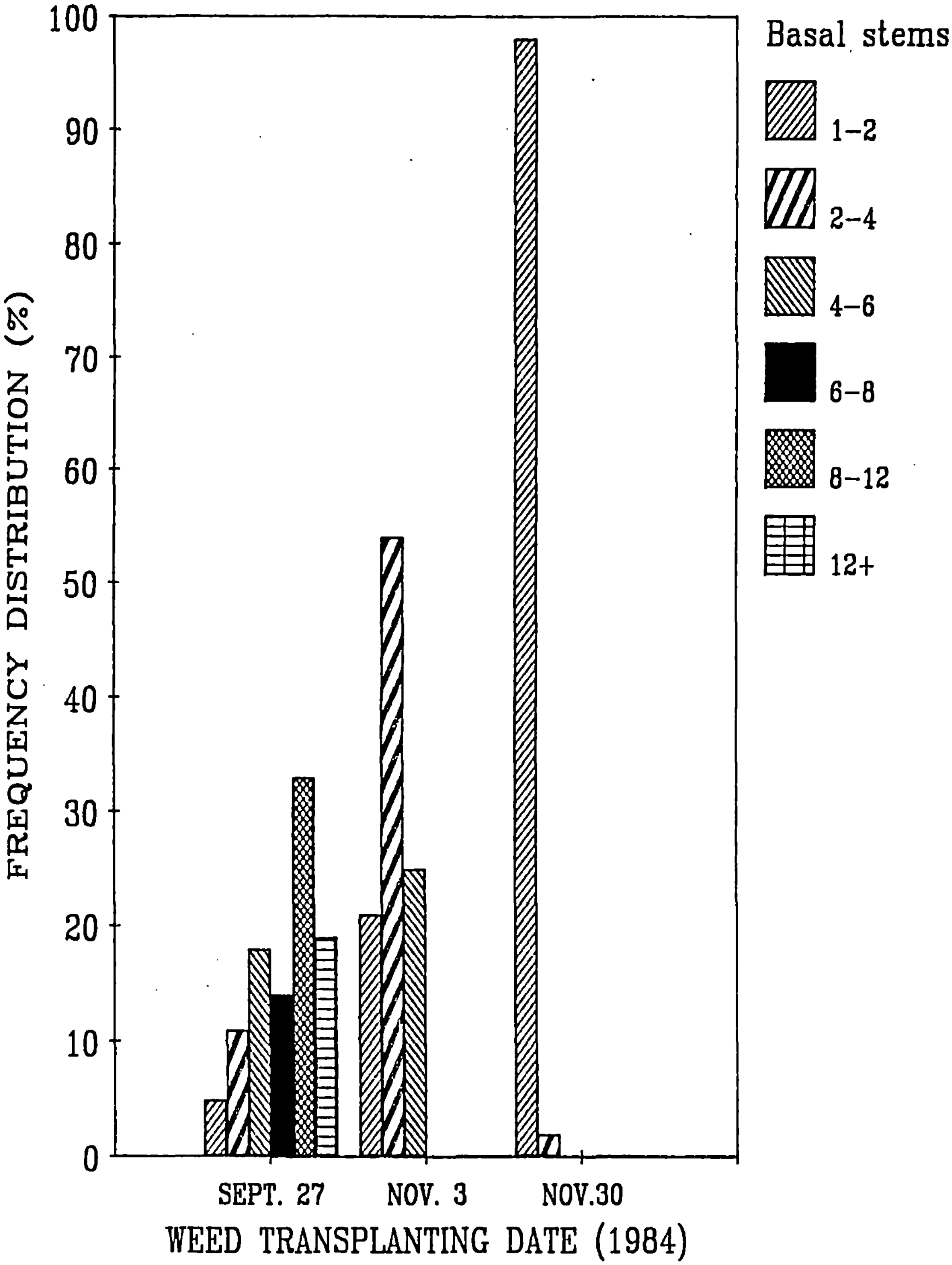

Figure 25. Effect of Corn Gromwell Transplanting Date, Averaged Over Density, on the Frequency of Corn Gromwell Plants With Various Numbers of Basal Stems/Plant on June 2, 1985

attributed to failure of some stems to develop appreciably before the plant matured and died. In contrast, none of the early or late November transplanted plants had as many as 8 basal stems by June 2, 1985. On June 2, most early November transplanted plants had 2 to 4 stems, and only 2% of the late November transplanted plants developed more than one basal stem.

Due to a great deal of variability in wheat yields it was not possible to draw firm conclusions regarding corn gromwells ability to compete with winter wheat (Table XVIII). However corn gromwell did not appear to be a strong competitor.

The results of the corn gromwell density study indicated that early transplanting, i.e. September vs October or November, results in much more aggressive growth of corn gromwell and much higher levels of seed (nutlet) production. The greater height and number of basal stems of the majority of corn gromwell plants also indicates that the earlier weeds would contribute much more foreign matter to harvested wheat than later developing plants would. Since the corn gromwell matured before wheat harvest, the extra plant material would not likely increase the moisture content of harvested wheat.

Effect of Foraging on Light Interception by Wheat and Subsequent Effects on Musk Thistle Growth

Simulated foraging in November, 1983 reduced the height of all three wheat varieties from over 30 cm to less than 10 cm. Foraging reduced sunlight interception from approximately 80% to 50% or less (Table XIX). There were no significant differences between varieties in their ability to intercept light either before or after foraging. When measured in February, 1984, thistles growing in plots where the wheat

TABLE XVIII

EFFECT OF CORN GROMWELL ON THE YIELD OF WINTER WHEAT

	Date of Wheat Harvest							
	June 5, 1984				June 2, 1985			
	(Date of Corn Gromwell Transplanting)							
Corn Gromwell Density	Sept. 29, 1983	Oct. 26, 1983	Nov. 22, 1983	Mean	Sept. 27, 1984	Nov. 3, 1984	Nov. 30, 1984	Mean
(weeds/m^2)		(Kg/ha)				(Kg/ha)		
0	2701	3302	3364	3122	3335	1998	2044	2459
2	1862	1745	2233	1947	2412	2232	2819	2488
4	2054	1806	3510	2457	2578	2333	1913	2275
8	2305	1890	1850	2015	2793	2433	2443	2556
16	2248	3425	3794	3156	2826	1791	2384	2334
32	3415	1556	2062	2344	2428	2023	2684	2377
L.S.D. 0.05[1] =		[NSD]		NSD		[NSD]		NSD

[1] L.S.D.'s in [ ], are used to compare the date of weed transplanting by weed density interaction, all other L.S.D. values are used to compare weed density means averaged over weed transplanting dates.

TABLE XIX

EFFECT OF FORAGING ON WHEAT PLANT HEIGHT AND LIGHT INTERCEPTION BY THE WHEAT CANOPY (1983-1984)

	Wheat Varieties											
	Osage			Newton			TAM W101			Foraging Treatment		
Parameters	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Foraged	Not Foraged	L.S.D. 0.05
					(Foraged November 17, 1983)							
Wheat Plant height (cm)	8.0	30.9	[19.5]	8.2	33.2	[20.7]	7.9	30.1	[19.0]	8.1	31.4	(2.4)
Wheat Canopy Light Interception (%)	32.7	83.7	[58.2]	47.4	78.7	[63.0]	65.4	82.4	[66.2]	48.5	81.6	(18.1)
					(Foraged February 24, 1984)							
Wheat Plant Height (cm)	16.1	40.1	[28.1]	18.1	41.8	[29.9]	20.3	42.2	[31.2]	18.1	41.4	(1.6)
Wheat Canopy Light Interception (%)	15.7	77.0	[47.9]	17.7	73.4	[45.6]	20.2	80.2	[50.2]	17.8	76.9	(5.0)

L.S.D. values, in ( ), are to compare foraging treatments averaged over varieties, there were no significant variety by foraging treatment interactions or variety main effects.

forage had been removed in November had shorter rosette leaves than thistles growing in unforaged wheat (Table XX). It would appear that light interception by the unforaged wheat stimulated rosette leaves to expand their length. In the field these rosette leaves often were not prone, but rather tended to bend upward. On February 24, 1984, before forage was again removed the wheat was 40 to 42 cm tall (Table XIX). Foraging decreased wheat height by approximately 50% and substantialy decreased light interception. However there were no differences in the plant height of the three wheat varieties due to foraging. As in February, in April the leaves were larger on the thistles in unforaged wheat (Table XX).

There were no significant 3-way interactions between the foraging treatment, musk thistle presence (0 or 32 plants/m^2) and wheat varieties in the wheat height or light interception data in 1983-1984. Also, there was no significant musk thistle density by foraging treatment interaction or variety by foraging treatment interaction. Therefore, to determine whether the musk thistles affected the length of unforaged wheat and to compare the different varieties for their light interception, only the unforaged plots were included in the analysis for data in Table XXI. On November 17, 1983, the presence of 32 musk thistles/m^2 had slightly decreased wheat height, averaged over varieties (Table XXI). Averaged over musk thistle presence, the Newton wheat was slightly taller than the TAM W101 wheat. There was no effect of the musk thistle on light interception and no differences between varieties in light interception ability. On February 24, there was still no musk thistle or variety effect on light interception.

There was no variety by foraging treatment interaction in the musk thistle vegetative growth data collected June 5, 1984. However there

TABLE XX

EFFECT OF FORAGING ON THE GROWTH AND DEVELOPMENT OF MUSK THISTLE (1983-1984)

	February 17, 1984		April 5, 1984		June 5, 1984 (Weed Harvest)				
Foraging Treatments[1]	Rosette Radius	Leaves/ Plant	Leaf Length	Leaves/ Plant	Plant Height	Rosette Radius	Leaves/ Plant	Fresh Wt./Plant	Dry Wt./Plant
	(cm)		(cm)		(cm)	(cm)		(g)	(g)
Foraged	6.0	5.9	5.4	6.3	16.6	8.4	12.5	6.7	1.3
Not Foraged	6.9	6.0	6.2	6.1	12.9	7.9	10.7	4.7	0.7
L.S.D. 0.05 =	0.4	NSD	0.7	NSD	NSD	NSD	1.8	1.9	0.4

[1]The wheat was foraged on November 17, 1983 and February 17, 1984.

TABLE XXI

EFFECT OF MUSK THISTLES ON THE HEIGHT OF AND LIGHT INTERCEPTION BY UNFORAGED WHEAT[1] (1983-1984)

	Musk Thistle Plants/m^2												
	Osage			Newton			TAM W101			L.S.D.[2] 0.10	Density Means		L.S.D. 0.10
Parameters	0	32	Mean	0	32	Mean	0	32	Mean		0	32	
					(Measured November 17, 1983)								
Wheat Plant height (cm)	32.0	29.9	[30.9]	35.4	31.1	[332]	30.30	30	[30.1]	[2.4]	32.6	30.3	(1.9)
Wheat Canopy Light Interception (%)	93.5	89.4	[91.4]	92.1	84.4	[88.2]	94.3	88.0	[91.1]	[NSD]	93.3	87.3	(NSD)
					(Measured February 24, 1984)								
Wheat Plant Height (cm)	38.4	41.9	[40.1]	42.9	40.8	[41.8]	40.3	44.1	[42.2]	[NSD]	40.5	42.3	(4.5)
Wheat Canopy Light Interception (%)	79.5	74.6	[77.1]	76.2	70.5	[73.5]	78.1	82.3	[80.2]	[NSD]	77.9	75.9	(NSD)

[1]Foraged plots were not included in this analysis.

[2]L.S.D.'s in [ ], are to compare variety means for each parameter which are also in [ ], L.S.D.'s in ( ), are to compare musk thistle density means, there are no significant musk thistle density by variety interactions.

were a few foraging treatment and variety main effects. Although no differences in leaves/plant due to foraging treatment were found in February or April, by June 5, the average musk thistle had more leaves and greater weight when grown in plots where wheat forage had been removed (Table XX). Also, average musk thistle height was much greater in Newton wheat (Table XXII). However, the harvest time categorization of all musk thistles into one of 3 growth stages, i.e. rosette, bolting, or head forming, did reveal a variety by growth stage interaction, a foraging treatment by growth stage interaction, and, at the 0.10 level of probability, a variety by foraging treatment by growth stage interaction. The variety by growth stage interaction was due to the presence of fewer plants remaining in the rosette stage in Newton wheat than in Osage wheat, and fewer plants with heads in the TAM W101 wheat than in the Newton wheat (Table XXIII). The foraging treatment by growth stage interaction was due to foraging decreasing the number of plants that remained in the rosette stage, but not statistically significantly increasing the percentage of plants in either of the other stages. The 3-way interaction occurred because removing the forage from Osage wheat did not affect the percentage of thistles that remained as rosettes or bolted, or initiated seed heads. However, foraging decreased the percentage of plants that remained as rosettes and increased the number with heads in Newton wheat. These results were not explainable by examining the forage removal or early season light interception data. Thus, light interception later in the season, probably after the wheat began to joint, must have varied between varieties. The increased bolting of musk thistle in Newton may be related to the lower number of tillers/plant characteristic of Newton.

TABLE XXII

EFFECT OF WHEAT VARIETY ON MUSK THISTLE GROWTH AND DEVELOPMENT (1983-1984)

Wheat Varieties	June 5, 1984 (Weed Harvest)				
	Plant Height	Rosette Radius	Leaves/ Plant	Fresh Wt./Plant	Dry Wt./Plant
	(cm)	(cm)		(g)	(g)
Osage	30.8	8.0	11.0	4.7	0.8
Newton	51.1	8.3	12.8	6.7	1.3
TAM W101	29.6	8.2	10.9	5.7	0.9
L.S.D. 0.05 =	NSD	NSD	NSD	NSD	NSD
L.S.D. 0.10 =	8.2	NSD	NSD	NSD	NSD

TABLE XXIII

EFFECT OF FORAGING AND WHEAT VARIETY ON THE PERCENT OF MUSK THISTLES IN THE ROSETTE STAGE, BOLTING STAGE OR SEED HEADS PRESENT STAGE AT WHEAT HARVEST (JUNE 5, 1984)

	Wheat Varieties										
	Osage			Newton			TAM W101			Mean	
Growth Stage	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Foraged	Not Foraged
	(%)										
Rosette	61	55	[55]	29	54	[41]	44	61	[52]	(45)	(57)
Bolting	16	14	[15]	28	17	[22]	27	20	[23]	(24)	(17)
Heads	23	31	[27]	43	29	[36]	29	19	[23]	(32)	(26)

L.S.D. 0.10 for comparing variety by growth stage by foraging treatment interaction = 17

L.S.D. 0.05 for comparing the variety by growth stage interaction means, averaged over foraging treatment, in [ ] = 12

L.S.D. 0.05 for comparing foraging treatment by growth stage interaction means, averaged across varieties, in ( ) = 10

Also, Osage is a later maturing variety that would be expected to begin jointing several days after TAM W101 or Newton.

Analysis of forage data collected in November, 1983 revealed no variety effect or variety by thistle presence interaction in the fresh weight data. However, 32 musk thistles/m^2 reduced forage dry weight and the forage nitrate content of TAM W101 wheat by approximately 15% and 30% respectively, and did not reduce forage production or nitrate content of the other varieties (Table XXIV). This reduction in wheat forage production and nitrate concentration was not apparent when forage was harvested in February (Table XXV). At that time, the only differences in the data occurred because Osage still had a lower nitrate content, averaged over the presence or absence of musk thistle, than Newton. The difference was not as great as it was in November, but it was still significant. Although this data does not reveal an affect of the weeds on nitrate content, it indicates that large differences in forage nitrate content can occur between varieties. The significance of this finding could be of value to farmers whose cattle sometimes die from nitrate poisoning while grazing on wheat pasture. From the standpoint of competability with weeds, however, the varieties would seem to vary only little prior to the jointing stage in their ability to produce quantities of vegetative growth to compete for light.

The presence or absence of musk thistle had no effect on wheat height or light interception in the 1984-1985 season. As in November, 1983, averaged over wheat varieties and musk thistle presence, foraging in November, 1984 reduced height of all three wheat varieties by approximately 67% (Table XXVI). In addition, Newton wheat was significantly shorter than either Osage or TAM W101 wheat in November, 1984. Light interception was decreased from over 67% to less than 11%

TABLE XXIV

EFFECT OF MUSK THISTLE ON WHEAT FORAGE PRODUCTION AND NITRATE CONCENTRATION (FORAGED NOVEMBER 17, 1983)

	Musk Thistle Plants/m^2										
	Osage			Newton			TAM W101			L.S.D. 0.05[1]	
Parameters	0	32	Mean	0	32	Mean	0	32	Mean	Variety Means	Interaction
Wheat Fresh Weight (Kg/m^2)	0.484	0.467	[0.475]	0.493	0.487	[0.490]	0.550	0.474	[0.512]	[NSD]	NSD
Wheat Dry Weight (Kg/m^2)	0.098	0.098	[0.098]	0.099	0.098	[0.099]	0.111	0.094	[0.103]	[NSD]	0.003
Wheat Nitrate Concentration (PPM)	2025	2025	[2025]	3025	3250	[3137]	2850	2000	[2425]	[841]	595

[1] L.S.D.'s in [ ], are to compare variety means which are also in [ ], all other L.S.D. values are used to compare musk thistle density by variety interaction.

TABLE XXV

EFFECT OF MUSK THISTLE ON WHEAT FORAGE PRODUCTION AND NITRATE CONCENTRATION (FORAGED FEBRUARY 24, 1984)

	Musk Thistle Plants/m^2										
	Osage			Newton			TAM W101			L.S.D. 0.05[1]	
Parameters	0	32	Mean	0	32	Mean	0	32	Mean	Mean	Interaction
Wheat Fresh weight (Kg/m^2)	0.169	0.180	[0.174]	0.163	0.174	0.168	0.186	0.199	[0.193]	[NSD]	NSD
Wheat Dry Weight (Kg/m^2)	0.080	0.078	[0.079]	0.070	0.072	[0.071]	0.078	0.083	[0.081]	[NSD]	NSD
Wheat Nitrate Concentration (PPM)	1500	1575	[1537]	1675	1725	[1700]	1600	1675	[1637]	[112]	NSD

[1] L.S.D.'s in [ ], are to compare variety means which are also in [ ], all other L.S.D. values are used to compare musk thistle density by variety interaction.

TABLE XXVI

EFFECT OF FORAGING ON WHEAT PLANT HEIGHT AND LIGHT INTERCEPTION BY THE WHEAT CANOPY (1984-1985)

	Wheat Varieties												
	Osage			Newton			TAM W101				Variety Means		
Parameters	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	L.S.D. 0.05	Foraged	Not Foraged	L.S.D. 0.05
(Foraged November 11, 1984)													
Wheat Plant Height (cm)	7.2	20.4	[13.8]	6.3	18.0	[12.1]	6.2	20.3	[13.3]	[1.1]	6.6	19.6	(0.8)
Wheat Canopy Light Interception (%)	10.3	65.0	[37.6]	10.4	69.1	[39.8]	10.2	68.0	[39.1]	[NSD]	10.3	67.3	(5.8)
(Foraged March 10, 1985)													
Wheat Plant Height (cm)	9.4	27.1	[18.2]	11.6	28.2	[19.9]	10.6	30.0	[20.3]	[1.0]	10.5	28.4	(0.8)
Wheat Canopy Light Interception (%)	8.7	87.7	[48.2]	7.1	81.7	[44.4]	8.2	85.0	[46.6]	[NSD]	8.0	84.3	(4.0)

L.S.D.'s in [ ], are to compare variety means averaged over foraging treatments which are also in [ ], L.S.D. values in ( ), are to compare foraging treatments means averaged over varieties, there was not a significant variety by foraging treatment interaction.

by foraging. However, there was not a difference in light interception between the varieties in spite of the small difference in height (Table XXVI). Similar results were obtained in March, 1985, where a 63% reduction in the height of all three varieties occurred with foraging. In contrast to wheat height measurements in November 1984, where Newton was the shortest wheat, in March, 1985, Osage was significantly shorter than Newton and TAM W101. Although there was no variety by foraging treatment interaction in the light interception data after foraging in March, foraging again tremendously reduced light interception.

As in 1983-1984, averaged over wheat varieties, foraging did not affect the mean plant height or rosette radius of musk thistles when measured at wheat harvest in 1984-1985 (Table XXVII). However in 1985, as in 1984, foraging did increase both fresh and dry musk thistle weight. Musk thistle heads/plant were also increased by removing the wheat forage twice. In May, 1985 a few musk thistle weevils were detected, but no difference occurred due to the foraging treatment. In addition to the foraging treatment main effect mentioned above, there was again in 1985 a variety main effect on musk thistle height at harvest. However, the effect was not the same as the previous year. In 1984, the thistles in the Newton wheat were taller than thistles in Osage or TAM W101, and in 1985 the thistles in the TAM W101 were taller than the thistles in the Osage wheat, but not the Newton (Table XXVIII). It would appear that musk height data, averaged over foraging treatment could be clarified somewhat by examining the growth stage categorization data. Categorization of the growth stage of musk thistle on May 30, 1985 revealed a 3-way interaction between variety, growth stage and foraging treatment at the 0.20 level of probability, a variety by growth stage interaction at the 0.05 level of probability and a foraging

TABLE XXVII

EFFECT OF FORAGING ON THE GROWTH AND DEVELOPMENT OF MUSK THISTLE (1984-1985)

	November 25, 1984	May 30, 1985 (Weed Harvest)						
Foraging Treatments[1]	Leaves/ Plant	Plant Height	Rosette Radius	Leaves/ Plant	Fresh Wt./Plant	Dry Wt./Plant	Heads/ Plant	Weevils/ Plant[2]
		(cm)		(cm)	(g)	(g)		
Foraged	8.9	80.4	18.7	14.2	23.3	7.3	2.3	0.1
Not Foraged	8.4	76.1	40.5	14.1	15.2	4.6	1.5	0.0
L.S.D. 0.05 =	NSD	NSD	NSD	NSD	8.5	2.6	0.7	NSD

[1] The wheat was foraged on November 11, 1984 and March 10, 1985.

[2] Refers to the number of musk thistle weevils per musk thistle plant.

TABLE XXVIII

EFFECT OF WHEAT VARIETY ON MUSK THISTLE GROWTH AND DEVELOPMENT (1985)

Wheat Varieties	May 30, 1985 (Weed Harvest)				
	Plant Height	Rosette Radius	Leaves/ Plant	Fresh Wt./Plant	Dry Wt./Plant
	(cm)	(cm)		(g)	(g)
Osage	68.1	12.3	48.8	15.0	4.8
Newton	75.5	16.0	27.3	20.8	6.0
TAM W101	93.2	14.2	19.7	22.1	7.1
L.S.D. 0.05 =	21.4	NSD	NSD	NSD	NSD
L.S.D. 0.10 =	--	2.9	NSD	NSD	NSD

treatment by growth stage interaction at the 0.20 level of probability. The same interactions were present in 1984 at the 0.10, 0.05 and 0.05 levels of probability respectively. The variety by growth stage interaction occurred because the population of musk thistle growing in TAM W101 wheat had fewer rosette plants, fewer bolting plants, and more plants with heads than thistles growing in Osage wheat or Newton wheat (Table XXIX). The foraging treatment by variety by growth stage interaction occurred, because as in 1984, foraging did not decrease thistles remaining as rosettes in Osage or TAM W101 wheat, but did decrease thistles remaining as rosettes in Newton wheat. Also there were fewer plants with heads in the unforaged compared to the foraged Newton and TAM W101 wheat.

The effect of foraging and wheat varieties on the maturity of musk thistle was further examined by analyzing the relative maturity of the musk thistles that developed seed heads. Averaged over varieties, 82% of the musk thistles growing in foraged plots developed heads as compared to only 74% in the unforaged plots (Table XXIX). Again averaged over varieties musk thistles growing in unforaged plots developed an average of 0.31 heads/plant, whereas the musk thistles growing in foraged plots developed an average of 0.47 heads/plant (Table XXX). The results of the comparison of maturity stage means averaged over variety and foraging treatment revealed that the maturity stages of bracts closed and pappus present were the most common among all maturity stages present at wheat harvest and the bracts open stage was present more often than the pappus expanded and mature seed stages. The maturity stage by foraging treatment interesting at the 0.20 level of probability was due to foraging increasing the number of musk thistles with bracts closed and pappus present maturity stages, but not

TABLE XXIX

EFFECT OF FORAGING AND WHEAT VARIETY ON THE PERCENT OF MUSK THISTLES IN EACH GROWTH STAGE AT WHEAT HARVEST (MAY 30, 1985)

Growth Stage	Wheat Varieties									Foraging Treatment by Growth Stage Mean	
	Osage			Newton			TAM W101				
	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Foraged	Not Foraged
Rosette	19	16	[17]	13	20	[16]	6	11	[8]	(13)	(16)
Bolting	10	10	[10]	5	19	[12]	2	3	[2]	(6)	(11)
Heads	71	74	[72]	82	63	[72]	92	86	[89]	(82)	(74)

L.S.D. 0.20 for comparing variety by growth stage by foraging treatment interactions = 10.

L.S.D. 0.05 for comparing the variety by growth stage interaction means, averaged over foraging treatments, in [ ] = 8.

L.S.D. 0.20 for comparing foraging treatment by growth stage interaction means, averaged over varieties in ( ) = 6.

TABLE XXX

EFFECT OF FORAGING AND WHEAT STATURE ON THE RELATIVE MATURITY OF MUSK THISTLE AT WHEAT HARVEST (MAY 30, 1985)

Seed Head[1] Maturity	Not Foraged				Foraged				
	Osage[2]	Newton	TAM W101	Mean	Osage	Newton	TAM W101	Mean	Means
	-----Mean number of seed heads per plant for each maturity stage-----								
Bracts closed	0.48	0.48	0.58	(0.51)	0.60	1.10	0.80	(0.83)	0.67
Bracts open	0.30	0.30	0.25	(0.28)	0.33	0.48	0.48	(0.43)	0.35
Pappus present	0.43	0.48	0.65	(0.52)	0.65	0.78	0.73	(0.72)	0.62
Pappus expanded	0.03	0.13	0.13	(0.09)	0.28	0.15	0.13	(0.19)	0.14
Mature seed	0.10	0.18	0.18	(0.15)	0.08	0.23	0.30	(0.20)	0.17
Means		[0.31]				[0.47]			

L.S.D. 0.05 for comparing foraging treatment means averaged over maturity stage and variety, in [ ] = 0.08

L.S.D. 0.05 for comparing maturity stage means averaged over variety and foraging treatments = 0.12

L.S.D. 0.20 for comparing maturity stage by foraging treatment interaction means, in ( ), averaged over variety = 0.17

[1]Musk thistle maturity stages are illustrated in Figure 2.

[2]The wheat stature factor is defined as: Osage - tall stature; Newton-medium short stature; TAM W101 - short stature.

increasing the bracts open, pappus expanded or mature seed stages. There was not a variety by foraging treatment by maturity stage interaction. These results are interesting because as discussed previously, thistles grown in Osage wheat were significantly shorter than those in TAM W101 wheat and the number of thistles with heads was less in Osage wheat than TAM W101 (Tables XXVIII and XXIX). Focusing on only the musk thistles that had heads at wheat harvest, at least 60% of that population had at least one head that reached the pappus present, pappus expanded or mature seed stage of development (Figure 26).

Musk thistle had no effect on fresh forage weight, dry weight and forage nitrate concentration of Osage, Newton and TAM W101 wheat at either foraging date in 1984-1985 (Table XXXI). Also, no variety differences were found in forage production and nitrate concentration in November, 1984. However, in March 1985, Newton wheat had a significantly higher nitrate concentration than Osage wheat (Table XXXII).

At the 0.10 level of probability there was a significant variety by foraging treatment interaction in the wheat yield data for 1983-1984. In unforaged wheat plots Newton yielded significantly higher than Osage or TAM W101 wheat whereas there was no difference in the variety yields in foraged plots. Also, the foraging treatment reduced the wheat yields of all three wheat varieties. The yield of TAM W101 wheat was significantly lower than yields of Osage or Newton when averaged over density and foraging treatment. Musk thistle density had no effect on the wheat yields in 1983-1984. Also, there was not a significant foraging treatment by density by variety interaction (Table XXXIII).

In 1984-1985 there was not a significant 3-way interaction between density, foraging treatment and variety in the wheat grain yield data.

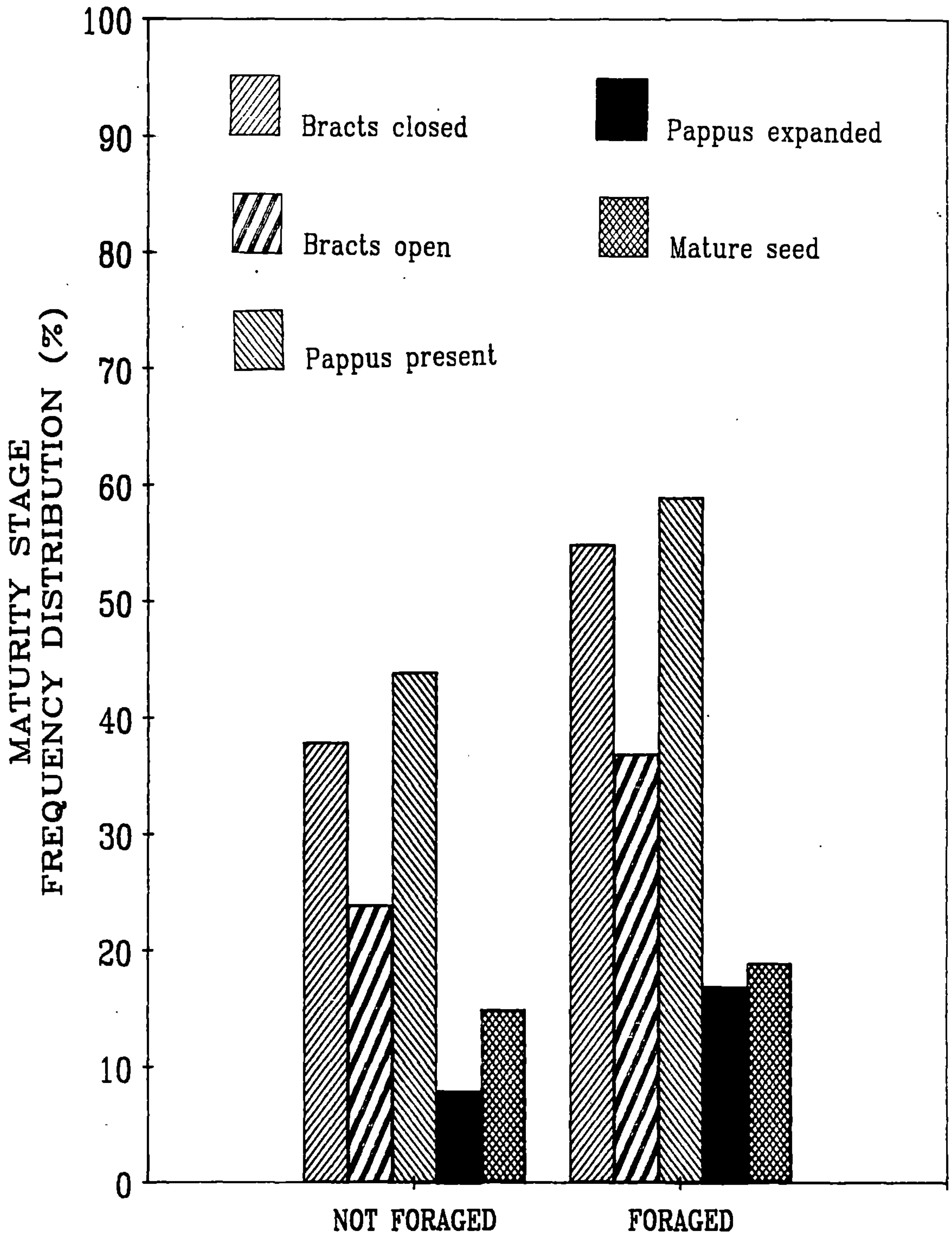

Figure 26. Frequency of Musk Thistle Seed Head Maturity Stages in Foraged and Unforaged Wheat on May 30, 1985 Averaged Over Varieties

TABLE XXXI

EFFECT OF MUSK THISTLE ON WHEAT FORAGE PRODUCTION AND NITRATE CONCENTRATION (FORAGED NOVEMBER 11, 1984)

	Musk Thistle Plants/m^2													
	Osage			Newton			TAM W101			L.S.D.[1] 0.05		Means		L.S.D. 0.05
Parameters	0	32	Mean	0	32	Mean	0	32	Mean	Mean	Interaction	0	32	
Wheat Fresh Weight (Kg/m^2)	0.292	0.350	[0.321]	0.267	0.288	[0.278]	0.295	0.333	[0.314]	NSD	[NSD]	0.285	0.324	(NSD)
Wheat Dry Weight (Kg/m^2)	0.061	0.069	[0.065]	0.051	0.053	[0.052]	0.058	0.063	[0.061]	NSD	[NSD]	0.057	0.062	(NSD)
Wheat Nitrate Concentration (PPM)	9075	9700	[9388]	12000	10550	[11275]	9125	10450	[9788]	NSD	[NSD]	10067	10233	(NSD)

[1] L.S.D.'s in [ ], are to compare variety means, averaged over density, which are also in [ ], L.S.D. values in ( ), are to compare density means averaged over variety, all other L.S.D. values are used to compare musk thistle density by variety interaction.

TABLE XXXII

EFFECT OF MUSK THISTLE ON WHEAT FORAGE PRODUCTION AND NITRATE CONCENTRATION (FORAGED MARCH 10, 1985)

	Musk Thistle Plants/m^2									
	Osage			Newton			TAM W101			L.S.D. 0.05[1]
Parameters	0	32	Mean	0	32	Mean	0	32	Mean	Mean
Wheat Fresh Weight (Kg/m^2)	0.579	0.531	[0.555]	0.606	0.587	[0.596]	0.444	0.479	[0.462]	[NSD]
Wheat Dry Weight (Kg/m^2)	0.157	0.145	[0.151]	0.158	0.152	[0.155]	0.131	0.139	[0.135]	[NSD]
Wheat Nitrate Concentration (PPM)	1850	1566	[1708]	3500	3450	[3475]	2825	2225	[2525]	[1143]

[1] L.S.D.'s in [ ], are to compare variety means, averaged over density, which are also in [ ], all other L.S.D. values are used to compare musk thistle density by variety interaction.

TABLE XXXIII

EFFECT OF MUSK THISTLE DENSITY AND FORAGING TREATMENT ON THE YIELD OF WINTER WHEAT (JUNE 5, 1984)

Wheat Varieties	Musk Thistle Plants/m^2						Variety Means
	Foraged			Not Foraged			
	0	32	Mean	0	32	Mean	
	(Kg/ha)						
Osage	977	1352	[1164]	1552	1882	[1717]	1440
Newton	1192	1035	[1113]	2155	2070	[2112]	1612
TAM W101	782	1205	[993]	1720	1675	[1697]	1345
Mean[1]	(1090)			(1842)			

L.S.D. 0.05 for comparing foraging treatment means which are in ( ), averaged over density and variety = 179

L.S.D. 0.05 for comparing variety means, averaged over density and foraging treatment = 219.

L.S.D. 0.10 for comparing the variety by foraging treatment interaction which are in [ ], averaged over foraging treatment = 257

[1] Foraging treatment means in ( ), are averaged over density and variety.

However as in the previous year, there was a significant variety by foraging treatment interaction. Foraging increased the yield of Osage wheat while Newton was unaffected by foraging and TAM W101 wheat yield was reduced by foraging. TAM W101 wheat had a higher grain yield than Osage or Newton wheat when averaged over density and foraging treatment. Unlike the results in 1983-1984, the foraging treatment means when averaged over density and variety were not significantly different (Table XXXIV). As with the musk thistle density experiments, wheat yields again were highly variable from year to year and within a year. Determination of the competitive affects of musk thistle is difficult due to this variability. Also, the response of the wheat varieties to the foraging treatment were inconsistant from year to year.

Effect of Foraging on Light Interception by Wheat and Subsequent Effect on Corn Gromwell Growth

The presence of corn gromwell at a density of 32 plants $/m^2$ had no affect on a wheat plant height or light interception of foraged and unforaged wheat, therefore the height and light interception data in Table XXXV is averaged over corn gromwell presence, i.e. 0 or $32/m^2$. Foraging in November, 1983 reduced wheat plant height by 48% thereby reducing sunlight interception by the wheat canopy more than 50% (Table XXXV). There were no variety effects or variety interactions in the height or light interception data. In February, 1984, measurements of leaf length and leaves/plant indicated that foraging had no effect on corn gromwell growth by early spring (Table XXXVI). Forage removal on February 24, 1984 reduced mean wheat height from 40 to 17.2 cm (Table XXXV). Averaged over forage removal treatment, Osage was slightly shorter than Newton or TAM W101, but there was not a forage removal

TABLE XXXIV

EFFECT OF MUSK THISTLE DENSITY AND FORAGING TREATMENT ON THE YIELD OF WINTER WHEAT (MAY 30, 1985)

Wheat Varieties	Musk Thistle Plants/m^2						Variety Means
	Foraged			Not Foraged			
	0	32	Mean	0	32	Mean	
	(Kg/ha)						
Osage	3074	2882	[2978]	1817	2591	[2204]	2591
Newton	2690	2684	[2687]	2608	3030	[2819]	2753
TAM W101	2893	2935	[2914]	3889	3649	[3769]	3341
Means[1]	(2860)			(2951)			

L.S.D. 0.05 for comparing the variety by foraging treatment interaction which are in [ ], averaged over density = 442

L.S.D. 0.05 for comparing variety means, averaged over foraging treatment and density = 312.

[1] There was not a significant difference between foraging treatments which are in ( ), averaged over variety and density.

TABLE XXXV

EFFECT OF FORAGING ON WHEAT PLANT HEIGHT AND LIGHT INTERCEPTION BY THE WHEAT CANOPY (1983-1984)

	Wheat Varieties													
	Osage			Newton			TAM W101			L.S.D. 0.05		Means		
Parameters	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Foraged	Not Foraged	Mean	Mean	Interaction	Not Foraged	Foraged	L.S.D. 0.05
(Foraged November 17, 1983)														
Wheat Plant Height (cm)	12.7	27.2	[20.0]	13.4	24.8	[19.1]	13.7	23.7	[18.7]	[NSD]	NSD	13.3	25.3	(5.1)
Wheat Canopy Light Inter-ception (%)	43.9	93.7	[68.8]	45.7	95.0	[70.4]	44.2	88.8	[66.5]	[NSD]	NSD	44.6	92.5	(5.0)
(Foraged February 24, 1984)														
Wheat Plant Height (cm)	15.8	36.9	[26.3]	17.0	43.0	[30.0]	19.0	40.0	[29.5]	[2.4]	NSD	17.2	40.0	(2.0)
Wheat Canopy Light Inter-ception (%)	16.6	68.6	[42.6]	18.6	71.6	[45.1]	21.7	67.5	[44.6]	[NSD]	NSD	19.0	69.2	(4.1)

L.S.D.'s in [ ], are to compare variety means averaged over foraging treatments which are also in [ ], L.S.D.'s in ( ), are to compare foraging treatments averaged over varieties, there were no variety by foraging treatment interactions.

TABLE XXXVI

EFFECT OF FORAGING AVERAGED OVER VARIETIES ON THE GROWTH AND DEVELOPMENT OF CORN GROMWELL (1983-1984)

	February 23, 1984		April 6, 1984		June 5, 1984 (Weed Harvest)				
Foraging Treatment[1]	Leaf Length	Leaves/ Plant	Plant Height	Flowers/ Plant	Plant Height	Basal Stems/Plant	Fresh Wt./Plant	Dry Wt./Plant	Calyxes/ Plant
	(cm)		(cm)		(cm)		(g)	(g)	
Foraged	5.3	14.1	13.1	2.2	31.8	0.3	12.0	6.3	16.7
Not Foraged	5.4	12.1	15.2	1.5	35.5	0.1	11.0	4.7	44.9
L.S.D. 0.05 =	NSD	NSD	NSD	0.4	2.5	NSD	NSD	1.2	NSD

[1] Wheat was foraged on November 17, 1983 and February 24, 1984.

treatment by variety interaction. Foraging reduced the light interception by the wheat canopy from 69.2% to 19.0%. There was not a significant difference in light interception by the three varieties, or a variety by forage removal treatment interaction. This light interception data indicates that height is not the only factor controlling light interception since Osage was significantly shorter than TAM W101 or Newton, but did not intercept significantly less light. On April 6, 1984 corn gromwell plant height was not affected by the forage removal treatment but the number of flowers/plant was increased by foraging. By June 5, 1984 both plant height and dry weight of the corn gromwell that grew in foraged wheat was greater than the height and weight of plants that grew in unforaged wheat. But, no significant differences were detected due to the forage removal treatment in fresh weight, basal stems/plant or calyxes/plant (Table XXXVI). There were no significant wheat variety effects on corn gromwell plant height, fresh weight, dry weight or calyxes/plant at wheat harvest in June, 1984, nor were there any variety by foraging treatment interactions. However, at the 0.10 level of probability the number of basal stems/plant was significantly less in the Newton and TAM W101 wheat than in the Osage wheat (Table XXXVII).

Wheat forage production data collected on November, 1983 revealed a significant variety by corn gromwell presence interaction due to a reduction of nitrate concentration in Newton wheat by the presence of 32 corn gromwell plants/m^2 (Table XXXVIII). Averaged over the presence or absence of corn gromwell, the TAM W101 wheat produced more forage on a fresh weight basis than Osage or Newton. As was the case in the musk thistle experiments Newton had a higher nitrate content than TAM W101 or Osage. There were no significant differences in the dry forage weight

TABLE XXXVII

EFFECT OF WHEAT VARIETY ON CORN GROMWELL GROWTH AND DEVELOPMENT AT WHEAT HARVEST

	June 5, 1984				
Wheat Varieties	Plant Height	Basal Stems/Plant	Fresh Wt./Plant	Dry Wt./Plant	Calyxes/ Plant
	(cm)		(g)	(g)	
Osage	34	0.58	11.8	6.0	39
Newton	34	0.12	11.6	5.8	15
TAM W101	31	0.10	10.7	4.6	38
L.S.D. 0.05 =	NSD	NSD	NSD	NSD	NSD
L.S.D. 0.10 =	NSD	0.26	NSD	NSD	NSD

TABLE XXXVIII

EFFECT OF CORN GROMWELL ON WHEAT FORAGE PRODUCTION AND NITRATE CONCENTRATION (FORAGED NOVEMBER 17, 1983)

	Corn Gromwell Plants/m^2										
	Osage			Newton			TAM W101			L.S.D. 0.05[1]	
Parameters	0	32	Mean	0	32	Mean	0	32	Mean	Mean	Interaction
Wheat Fresh Weight (Kg/m^2)	0.408	0.476	[0.442]	0.417	0.447	[0.432]	0.549	0.505	[0.527]	[0.069]	NSD
Wheat Dry Weight (Kg/m^2)	0.101	0.098	[0.099]	0.088	0.104	[0.096]	0.129	0.114	[0.121]	[NSD]	NSD
Wheat Nitrate Concentration (PPM)	1600	1800	[1700]	3025	1950	[2487]	1850	1525	[1687]	[552]	788

[1] L.S.D.'s in [ ], are to compare variety means, averaged over density, for each parameter which are also in [ ], interaction L.S.D. values are used to compare corn gromwell density by variety interaction.

among the three varieties. The only significant difference found in the forage data collected on February 24, 1984 was that Newton and TAM W101 again had higher nitrate contents than Osage wheat (XXXIX).

In the 1984-1985 experiment there was a significant variety by density by foraging treatment interaction at the 0.10 level of probability for wheat plant height in November. The presence of corn gromwell at 32 plants/m^2 reduced the height of unforaged Newton and TAM W101 wheat but not Osage, and reduced the height of foraged Newton (XL). The forage removal treatment by variety interaction in the plant height data occurred because unforaged Osage was taller than unforaged Newton or TAM W101, but after forage removal there were no differences in height between varieties. There was not a foraging treatment by density interaction in plant height in November, 1984. In the plots with no corn gromwell present, data on light interception was collected by placing the sensor on the soil surface. In plots containing corn gromwell, the sensor was placed at each weeds apex. Thus when the light interception data collected immediately after forage removal in November was analyzed, a corn gromwell presence by foraging treatment interaction was found. The interaction occurred because, when light interception was measured at ground level, 69% of the light was intercepted by unforaged wheat, whereas when measured at the top of the gromwell plants, only 37.2% of the light was being intercepted. In contrast, once the upper forage was removed, light interception was less than 6% at both the soil surface and the top of the weeds (Table XLI). As in November, 1984, a significant variety by foraging treatment by corn gromwell presence interaction was found at the 0.10 level of probability in wheat plant height in March, 1985. The interaction occurred because corn gromwell reduced the height of unforaged TAM W101 wheat but not the

TABLE XXXIX

EFFECT OF CORN GROMWELL ON WHEAT FORAGE PRODUCTION AND NITRATE CONCENTRATION (FORAGED FEBRUARY 24, 1984)

	Corn Gromwell Plants/m^2										
	Osage			Newton			TAM W101			L.S.D. 0.05[1]	
Parameters	0	32	Mean	0	32	Mean	0	32	Mean	Mean	Interaction
Wheat Fresh Weight (Kg/m^2)	0.151	0.147	[0.149]	0.151	0.137	[0.144]	0.174	0.146	[0.160]	[NSD]	NSD
Wheat Dry Weight (Kg/m^2)	0.065	0.059	[0.062]	0.065	0.054	[0.059]	0.069	0.058	[0.064]	[NSD]	NSD
Wheat Nitrate Concentration (PPM)	1650	1700	[1675]	1950	1925	[1937]	1875	1950	[1912]	[110]	NSD

[1] L.S.D.'s in [ ], are to compare variety means, averaged over density, for each parameter which are also in [ ], there was not a significant corn gromwell density by variety interaction.

TABLE XL

EFFECT OF CORN GROMWELL DENSITY, FORAGING TREATMENT, AND WHEAT VARIETY ON WHEAT PLANT HEIGHT AND LIGHT INTERCEPTION BY THE WHEAT CANOPY (1984-1985)

Parameters	Corn Gromwell Plants/m^2																			
	Osage						Newton						TAM W101						L.S.D. 0.10	
	Foraged			Not Foraged			Foraged			Not Foraged			Foraged			Not Foraged				
	0	32	Mean	0	32	Mean	0	32	Mean	0	32	Mean	0	32	Mean	0	32	Mean	Means	Interaction
(Foraged November 11, 1984)																				
Wheat Plant Height (cm)	6.5	7.0	[6.7]	20.8	21.5	[21.1]	7.5	6.2	[6.9]	20.6	17.6	[19.1]	5.9	6.2	[6.1]	21.1	17.0	[19.1]	[0.9]	1.2
Wheat Canopy Light Interception (%)	3.7	3.4	[3.5]	43.9	26.0	[34.9]	6.7	6.9	[6.8]	81.1	44.5	[62.8]	5.9	4.9	[5.4]	82.4	41.2	[61.8]	[4.9]	NSD
(Foraged March 10, 1985)																				
Wheat Plant Height (cm)	9.6	9.4	[9.5]	22.9	23.9	[23.4]	10.9	10.4	[10.6]	27.2	27.4	[27.3]	10.1	10.9	[10.5]	30.7	26.9	[28.8]	[0.6]	1.1
Wheat Canopy Light Interception (%)	26.4	3.17	[14.8]	84.8	37.5	[61.1]	15.8	6.3	[11.0]	85.1	47.0	[66.0]	25.74	6.1	[15.9]	85.6	42.9	[64.2]	[NSD]	NSD

[1] L.S.D.'s in [ ] are to compare foraging treatment by variety interaction, averaged over density, which are also in [ ], L.S.D.'s not in brackets are to compare foraging treatment by variety by density interaction.

TABLE XLI

EFFECT OF CORN GROMWELL ON WHEAT PLANT HEIGHT AND LIGHT INTERCEPTION BY THE WHEAT CANOPY, AVERAGED OVER VARIETIES (1984-1985)

	Corn Gromwell Plants/m^2				
	Means				
	Foraged		Not Foraged		
Parameter	0	32	0	32	L.S.D. 0.10[1]
(Foraged November 11, 1984)					
Wheat plant Height (cm)	6.6	6.5	19.9	18.7	NSD
Wheat Canopy Light Interception (%)	5.4	5.1	69.1	37.2	4.0
(Foraged March 10, 1985)					
Wheat Plant Height (cm)	10.0	10.4	26.9	26.2	NSD
Wheat Canopy Light Interception (%)	42.5	5.2	85.2	22.6	8.1

[1] L.S.D. values are to compare foraging treatment by density interaction averaged over varieties. There were no variety by foraging treatment interaction.

height of the other varieties, and corn gromwell did not affect the height of any variety when measured after forage was removed. Unforaged TAM W101 was the tallest wheat, whereas Osage was the shortest in March, 1985. This difference is probably due to earlier erection of pseudostems by the earlier maturing TAM W101. There was not a foraging treatment by weed density interaction in wheat plant height in March, 1985. However, as in November 1984, there was a significant foraging treatment by weed density interaction in light interception by the wheat canopy in March, 1985. Foraging reduced the light intercepted by the canopies of all three varieties (Table XL). In both the foraged and unforaged plots the light readings taken from the soil surface of the plots without corn gromwell and from the apex of the weed in the density plots, revealed that the wheat canopy was not effectively stopping light from penetrating to the weed. In plots with corn gromwell, only 5.2% of the sunlight was intercepted by the wheat canopy in the foraged plots and 22.6% of the sunlight was intercepted by the unforaged wheat (Table XLI).

Foraging had a significant effect on the growth and development of corn gromwell by the end of the growing season. Corn gromwell basal stems/plant and calyxes/plant in May, 1985 were increased over 50% due to the foraging treatment. As in 1984, foraging the wheat increased corn gromwell dry weight at wheat harvest. However, there was no difference in corn gromwell height between the foraged and unforaged plots (Table XLII). Wheat varieties also affected the growth of corn gromwell by the end of the growing season. Corn gromwell grown in TAM W101 wheat had greater plant height, dry weight and calyxes/plant than plants grown in Newton or Osage wheat. Corn gromwell plants grown in Newton wheat were taller than those grown in Osage wheat (Table XLIII).

TABLE XLII

EFFECT OF FORAGING ON THE GROWTH AND DEVELOPMENT OF CORN GROMWELL (1984-1985)

	November 25, 1984	May 30, 1985 (Weed Harvest)			
Foraging Treatments[1]	Flowers/ Plant	Plant Height	Basal Stems/Plant	Dry Wt./Plant	Calyxes/ Plant
		(cm)		(g)	
Foraged	4.00	68.96	18.79	12.64	205.79
Not Foraged	4.42	66.75	9.27	5.35	66.71
L.S.D. 0.05 =	NSD	NSD	2.43	3.22	44.88

[1] Wheat was foraged on November 11, 1984 and March 10, 1985.

TABLE XLIII

EFFECT OF WHEAT VARIETY ON CORN GROMWELL GROWTH AND DEVELOPMENT AT WHEAT HARVEST

	May 30, 1985			
Wheat Varieties	Plant Height	Basal Stems/Plant	Dry Wt./Plant	Calyxes/ Plant
	(cm)		(g)	
Osage	61	13.8	8.8	110
Newton	73	13.1	7.1	106
TAM W101	71	15.3	11.3	198
L.S.D. 0.05 =	8.51	NSD	3.2	71

There was a significant foraging treatment by variety interaction in the fresh weight of corn gromwell on May, 1985. In unforaged wheat there was not a difference in corn gromwell fresh weight. Foraging more than doubled fresh weight in all three wheat varieties, but corn gromwell grown in foraged TAM W101 wheat had much greater fresh weight than that grown in either other variety (Table XLIV).

There were no significant corn gromwell density by variety interactions in wheat foraged dry weight or wheat nitrate concentration data in November, 1984. However, the fresh weight of Osage was greater than Newton. TAM W101 had a significantly greater nitrate concentration than Osage and Newton in November, 1984. Corn gromwell did not affect forage production in November, 1984 (Table XLV). There were no differences found in the forage production of the three wheat varieties in March, 1985 (Table XLVI). Forage production and nitrate concentration of Osage, Newton and TAM W101 seemed not to be affected by corn gromwell, since only the nitrate concentration of Newton wheat in November, 1983 was significantly reduced by 32 corn gromwell plant/m^2.

In 1983-1984 there was not a significant foraging treatment by density by variety interaction. Also, there were no variety by foraging treatment, variety by density or density by foraging treatment interactions. However the foraging treatment, averaged over density and variety reduced wheat yields in 1983-1984. When variety means were averaged over density and foraging treatment, Newton was found to have the highest yield (Table XLVII).

In 1984-1985, there were no 3 way interactions present between density, variety and foraging treatment in the wheat grain yields. However, there was a significant variety by foraging treatment

TABLE XLIV

EFFECT OF WHEAT VARIETY AND FORAGING ON FRESH WEIGHT OF CORN GROMWELL AT WHEAT HARVEST (MAY 30, 1985)

	Wheat Varieties			Mean
	Osage	Newton	TAM W101	
	(grams/plant)			
Foraged	14.5	14.4	23.4	17.4
Not Foraged	7.3	6.8	8.9	7.7
L.S.D.[1] 0.05 =		6.9		[3.3]

[1] L.S.D. in [ ], is to compare foraging treatment main effect averaged over varieties and density, L.S.D. not in brackets is to compare variety by foraging treatment main effect, averaged over density.

TABLE XLV

EFFECT OF CORN GROMWELL ON WHEAT FORAGE PRODUCTION AND NITRATE CONCENTRATION (FORAGED NOVEMBER 11, 1984)

	Corn Gromwell Plants/m^2										
	Osage			Newton			TAM W101			L.S.D. 0.05[1]	
Parameters	0	32	Mean	0	32	Mean	0	32	Mean	Mean	Interaction
Wheat Fresh Weight (Kg/m^2)	0.456	0.356	[0.406]	0.317	0.379	[0.348]	0.436	0.354	[0.395]	[NSD]	NSD
Wheat Dry Weight (Kg/m^2)	0.088	0.074	[0.081]	0.061	0.069	[0.065]	0.085	0.067	[0.076]	[0.013]	NSD
Wheat Nitrate Concentration (PPM)	9275	8450	[8864]	7125	6625	[6875]	12526	13525	[13025]	[4131]	NSD

[1] L.S.D.'s in [ ], are to compare variety means, averaged over density for each parameter which are also in [ ], there was no significant corn gromwell density by variety interaction.

TABLE XLVI

EFFECT OF CORN GROMWELL ON WHEAT FORAGE PRODUCTION AND NITRATE CONCENTRATION (FORAGED MARCH 10, 1985)

	Corn Gromwell Plants/m^2										
	Osage			Newton			TAM W101			L.S.D. 0.05[1]	
Parameters	0	32	Mean	0	32	Mean	0	32	Mean	Mean	Interaction
Wheat Fresh Weight (Kg/m^2)	0.591	0.481	[0.536]	0.491	0.503	[0.497]	0.515	0.539	[0.527]	[NSD]	NSD
Wheat Dry Weight (Kg/m^2)	0.155	0.133	[0.144]	0.141	0.137	[0.139]	0.141	0.146	[0.144]	[NSD]	NSD
Wheat Nitrate Concentration (Kg/m^2)	1600	2150	[1875]	2800	2025	[2412]	2550	2725	[2637]	[NSD]	NSD

[1] L.S.D.'s in [ ], are to compare variety means, averaged over density for each parameter which are also in [ ], there was no significant corn gromwell density by variety interaction.

TABLE XLVII

EFFECT OF CORN GROMWELL DENSITY AND FORAGING TREATMENT ON THE YIELD OF WINTER WHEAT (JUNE 5, 1984)

Wheat Varieties	Corn Gromwell Plants/m^2: Foraged 0	Foraged 32	Foraged Mean	Not Foraged 0	Not Foraged 32	Not Foraged Mean	Variety Means
	(Kg/ha)						
Osage	990	1175	[1082]	1350	1700	[1525]	1304
Newton	1430	1267	[1348]	2057	2442	[2249]	1799
TAM W101	1310	827	[1068]	1422	1892	[1657]	1363
Means[1]	1243	1090		1610	2011		
	(1166)			(1810)			

L.S.D.[2] 0.05 for comparing foraging treatment by density interaction, averaged over variety = 420

L.S.D. 0.05 for comparing variety means, averaged over density and foraging treatment = 300

L.S.D. 0.05 for comparing foraging treatment averaged over density and variety means which are in ( ), = 170

[1] Density means averaged over variety.

[2] There was not a significant variety by foraging treatment interaction.

interaction. Foraging reduced the yields of TAM W101 and Newton but not the yield of Osage wheat. The yields of unforaged TAM W101 and Newton wheat were greater than the yield of unforaged Osage wheat, but there were no differences in the yields of foraged wheat varieties. Also, as in the previous year, at the 0.10 level of probability, foraging significantly reduced wheat yields (Table XLVIII). As with the wheat yields of all the experiments previously discussed, the variability in the yield data made it difficult to determine the competitive ability of corn gromwell.

Effect of Land Management on Musk Thistle Seed Head Production and Musk Thistle Weevils/Plant (1983, 1984, and 1985)

There was not a siginificant environment by year interaction in the number of musk thistle heads produced/plant. Musk thistles growing in the roadside and hay field environments produced 10.0 and 8.9 heads/plant respectively compared to thistles in the conventionally tilled wheat field and improved pasture which developed a three year average of 16.3 heads/plant (Table XLIX). These results could indicate a fertility response in the number of heads/plant produced, since the greatest number of heads/plant was found in environments which usually have a higher fertility level. The number of heads/plant produced in the conventionally tilled environment was much greater than in the density and foraging experiment. However, this survey was conducted each year in July whereas the density and foraging experiments were completed by the first week of June.

There was a significant year by environment interaction in the number of musk thistle weevils in one musk thistle plant. The

TABLE XLVIII

EFFECT OF CORN GROMWELL DENSITY AND FORAGING TREATMENT ON THE YIELD OF WINTER WHEAT (MAY 30, 1985)

Wheat Varieties	Corn Gromwell Plants/m^2 Foraged 0	Foraged 32	Foraged Mean	Not Foraged 0	Not Foraged 32	Not Foraged Mean	Variety Means
	(Kg/ha)						
Osage	3604	3380	[3492]	2930	3365	[3147]	3328
Newton	3681	3100	[3390]	3995	3817	[3906]	3648
TAM W101	3360	3190	[3275]	4164	3933	[4048]	3661
		(3386)			(3701)		

L.S.D.[1] 0.10 for comparing foraging treatment means, averaged over density and variety, which are in ( ), = 299

L.S.D. 0.05 for comparing variety by foraging treatment interaction, averaged over density, which are in [ ], = 518.

[1] There was not a significant difference between variety means.

TABLE XLIX

EFFECT OF LAND MANAGEMENT ON MUSK THISTLE SEED HEAD PRODUCTION AND MUSK THISTLE WEEVILS/PLANT (1983, 1984 AND 1985)

Environments	Musk Thistle Seed Heads Per Plant				Musk Thistle Weevils Per Plant			
	1983	1984	1985	Mean	1983	1984	1985	Mean
Conventional tilled wheat field (not grazed)	16.4	15.6	17.0	16.3	10.7	4.6	7.2	3.4
Unimproved Pasture (grazed)	10.2	15.2	12.8	12.7	1.6	1.2	4.4	3.7
Improved Pasture (grazed)	17.4	22.8	8.6	16.3	0.8	4.0	3.0	2.6
Roadside (mowed)	6.6	12.4	11.0	10.0	4.2	5.0	4.6	4.6
Hay Field (grazed and mowed)	8.8	9.6	8.4	8.9	4.2	1.4	3.4	3.0
Unimproved Pasture (not grazed or mowed)	12.6	13.4	12.8	12.9	6.6	7.6	8.2	7.5
L.S.D.[1] 0.05 =		NSD		[5.5]		3.8		[2.2]

[1] L.S.D.'s in [ ], are for comparing environment main effect averaged over years, L.S.D.'s not in brackets are for comparing year by environment interaction.

interaction was due to an increase in the number of weevils/plant in 1985 in the unimproved pasture environment compared to the two previous years. Averaged over the three year period the greatest number of weevils were found in conventionally tilled fields or unimproved pastures with the exception of 1985 were there was 8.2 weevils/plant found in the unimproved pasture environment. This data indicates that the musk thistle weevil may have a preference for musk thistles growing with higher fertility and that the weevil population is antagonized by grazing and/or mowing. These results also indicate a relatively stable weevil population, and do not indicate that he population density, i.e. weevils/plant, is increasing rapidly. They also indicated an ability of the weevil to readily infest musk thistles growing in cultivated fields.

Evaluation of the Seasonal Emergence Pattern of Corn Gromwell and Musk Thistle

Corn gromwell and musk thistle followed a winter annual emergence pattern in a clean tilled field. Nearly 60% of the total musk thistle seeds that emerged, had emerged by October 29, 1984. Eighty six percent of the total emerged corn gromwell had emerged by October 29, 1984 (Table L). The emergence pattern of both weed species seemed to follow the precipitation pattern. In the observation period from October 19, to October 29 over 50% of the total corn gromwell emergence and 40% of the total musk thistle emergence occurred during this period which accumulated 11.4 cm of precipitation. At the end of the observation period, about 35% of the seeds of each species had emerged.

TABLE L

EVALUATION OF THE SEASONAL EMERGENCE PATTERN OF CORN GROMWELL AND MUSK THISTLE

Observation Period	Musk Thistle	Corn Gromwell	Observation Period Precipitation
(1984)	Percent emergence of the total seed population		(cm)
Oct. 1 to Oct. 11[1]	0.9	10.0	0.5
Oct. 11 to Oct. 19	0.8	5.7	0.2
Oct. 19 to Oct. 29	17.6	16.6	11.4
Oct. 29 to Nov. 7	6.1	3.4	1.3
Nov. 7 to Nov. 24	8.7	1.5	3.8
Nov. 24 to May 30, 1985	0.0	0.0	26.1
Total	34	37.2	43.3
L.S.D. 0.05 =	(3.9)	(5.4)	---

[1] This experiment was initiated on October 1, 1984.

Control of Musk Thistle

Herbicide treatments applied March 19, 1985 that provided excellent control of musk thistle were 2,4-D LV at 0.56 kg ae/ha, dicamba + 2,4-D LV at 0.14 kg ae/ha + 0.42 kg ae/ha respectively, picloram + 2,4-D amine at 0.027 + 0.42 kg ae/ha, Lontrel 205 at 1.8 l/ha and bromoxynil + 2,4-D LV at 0.42 kg ae/ha + 0.56 kg ae/ha respectively (Table LI). Treatments that gave poor or no control of musk thistles were picloram at 0.027 kg ae/ha, chlorsulfuron + AG98 at 0.017 kg ai/ha + 1/2% v/v, chlorsulfuron + AG98 at 0.025 kg ai/ha + 1/2% v/v, DPX M6316 + AG98 at 0.017 kg ai/ha + 1/2% v/v, and DPX M6316 + AG98 at 0.017 kg ai/ha + 1/2% v/v. Only picloram at 0.027 kg ae/ha caused significantly more epinasty to 10 cm diameter musk thistle than to larger diameter musk thistle. No other herbicide or herbicide combination controlled a particular diameter of musk thistle better than another.

TABLE LI

EFFECT OF SPRING APPLICATION OF SELECTED HERBICIDES ON VARIOUS SIZES OF MUSK THISTLE

Herbicide Treatment	Rate	Percent Epinasty or Injury to Musk Thistles with various Rosette Diameters of Musk Thistle (March 24, 1985)						Musk Thistle Control
		10cm	20cm	30cm	40cm	50cm	Mean	(May 18, 1985)
	(kg ai or ae/ha)	(%)						(%)
1. 2,4-D LV	0.56	67.5	81.3	83.6	57.7	78.1	73.4	100
2. Dicamba + 2,4-D LV	0.14 + 0.42	72.5	93.1	91.2	85.8	86.4	85.6	100
3. Picloram	0.027	15.0	3.3	2.7	3.7	2.5	5.44	33
4. Picloram + 2,4-D amine	0.027 + 0.42	60.0	60.7	70.6	45.8	68.7	61.4	100
5. Chlorsulfuron + AG98[1]	0.017 + 1/2%	23.6	15.3	16.7	20.0	20.0	19.2	0
6. Chlorsulfuron + AG98	0.025 + 1/2%	16.6	24.7	20.4	16.8	22.0	20.2	0
7. DPX M6316 + AG98	0.17 + 1/2%	0	0	0.6	0.3	0	.18	0
8. DPX M6316 + AG98	0.015 + 1/2%	0	0	0.8	0.7	0	.32	0
9. (clopyralid + 2,4-D)[2]	(0.105 + 0.42)	100	96.4	91.5	93.4	98.7	95.8	100
10. bromoxynil + 2,4-D LV	0.42 + 0.056	100	97.5	97.5	93.3	100	97.4	90
11. Untreated Check	---	0	0	0	0	0	0	0
L.S.D.[3] 0.05 =			[8.2]				4.8	32

[1]AG98 = Surfactant.

[2]Clopyralid + 2,4-D = Lontrel 205, (0.105 + 0.42) = 1.861/ha.

[3]The L.S.D. in [ ], is to compare the herbicide by musk thistle diameter interactions.

CHAPTER V

SUMMARY

Weed density had little affect on the growth and reproduction of musk thistle or corn gromwell with densities ranging from 2 to 32 plants/m^2 differing little in their growth patterns. Thus this research indicates that there is very little evidence of intraspecific competition among corn gromwell plants or musk thistle plants. Neither corn gromwell or musk thistle were strong competitors with winter wheat.

Weed transplanting dates proved to be a critical factor in the growth and development of corn gromwell and musk thistle. Musk thistle and corn gromwell transplanted before October 1st developed at least 50% more plant biomass than plants transplanted at later dates. Also, the reproductive ability of each weed species was enhanced when transplanted in September. The number of calyxes per corn gromwell plant were increased in both growing seasons, while not only were the number of musk thistle heads increased but the maturity of the individual head was greater in those plants transplanted in September than those plants transplanted in October or November. Musk thistle and corn gromwell transplanted before October 1st grew much like winter annuals and each species were able to produce mature seed prior to wheat harvest. October and November musk thistles were not able to fully develop prior to wheat harvest, however corn gromwell plants transplanted in October and November were able to produce some mature seeds.

Simulated grazing reduced wheat plant height thereby reducing the amount of sunlight intercepted by the wheat canopies. Musk thistle leaves/plant, rosette radius and plant weight were increased due to the foraging treatment in 1983-1984. Similar results occurred in 1984-1985, where plant weight and heads/plant were greater in foraged plots compared to unforaged plots. Musk thistles growing in foraged plots had heads that were more mature than thistles growing in unforaged plots. Wheat stature had varying affects on musk thistle growth, however differences were detected in musk thistle growth when grown in the presence of different varieties. The musk thistle population growing in TAM W101 wheat developed more heads than plants growing in Osage or Newton wheat. Corn gromwell growth was also enhanced by the foraging treatment. By May, 1985 corn gromwell basal stems/plant and calyxes/plant were increased over 50% due to the foraging treatment. Wheat stature had inconsistent effect on corn gromwell growth, however corn gromwell fresh weight was greater in TAM W101 wheat than plants grown in Osage or Newton wheat. Neither corn gromwell or musk thistle had a consistent affect on wheat forage production, or wheat foliage nitrate concentration, however the nitrate concentration in Newton wheat was reduced by 30% at one foraging date.

The musk thistle weevil was found to prefer a more fertile environment over an unfertile environment. Over a three year period the population of musk thistle weevils did not increase and neither did the population of musk thistle plants.

Several herbicides provided excellent control of fall emerging musk thistles in 1985. Among these were dicamba, 2,4-D, bromoxynil and Lontrel 205. Musk thistle rosette diameter seemed not to affect the efficacy of any herbicides with the exception of picloram.

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APPENDIX

TABLE LII

RAINFALL DATA (0.1 cm QUANTITIES OR MORE) OF EXPERIMENTS - AGRONOMY RESEARCH STATION, STILLWATER, OKLAHOMA (SEPTEMBER 1, 1983 - JUNE 30, 1985)

Date	Centimeters	Date	Centimeters
September 5, 1983	0.2	April 16	0.1
September 13	2.8	April 20	0.4
September 14	0.1	April 21	0.9
September 16	0.4	April 27	1.7
September 20	1.5	April 30	0.1
September 26	0.1	May 6	2.4
October 4	0.2	May 20	1.6
October 7	0.9	May 25	2.1
October 8	0.4	May 26	0.6
October 11	0.9	June 12	2.0
October 12	0.4	June 19	0.6
October 17	0.9	June 20	2.7
October 18	0.1	June 21	0.5
October 19	1.1	June 26	5.4
October 20	6.1	June 28	1.2
October 21	8.2	June 29	0.9
November 1	0.1	July 7	0.1
November 2	0.2	July 11	0.1
November 7	0.4	July 12	1.0
November 9	0.5	July 27	0.3
November 10	0.2	August 5	0.1
November 19	1.6	August 8	0.2
November 23	1.6	August 11	1.5
November 27	0.8	August 22	0.5
December 3	0.3	August 30	0.3
December 19	0.6	September 3	0.4
January 10, 1984	0.2	September 16	0.2
January 15	0.1	September 18	0.4
January 17	0.2	September 27	0.5
February 9	0.8	September 28	1.4
February 27	0.9	October 10	0.4
March 4	0.9	October 14	0.2
March 12	1.0	October 16	1.5
March 17	0.3	October 21	1.3
March 19	0.9	October 25	2.1
March 23	3.8	October 27	6.5
March 24	2.6	October 28	0.2
March 28	2.0	November 1	1.3
March 29	0.2	November 17	1.7
March 31	1.3	November 18	2.1
April 3	0.2	November 27	0.4
April 8	2.4	December 5	1.1
April 10	0.2	December 13	0.1
April 11	1.3	December 14	2.1

TABLE LII (continued)

Date	Centimeters	Date	Centimeters
December 15	2.1	March 30	2.7
December 16	4.0	April 5	0.1
December 19	0.1	April 13	0.2
December 21	0.2	April 22	1.7
December 29	0.1	April 23	1.0
December 31	0.1	April 27	5.2
January 1, 1985	5.2	April 29	1.0
January 10	0.7	April 30	4.3
January 27	1.1	May 7	0.5
January 28	0.7	May 8	0.3
February 5	0.5	May 13	1.2
February 21	3.9	May 14	0.7
February 23	0.4	May 21	0.2
February 24	6.4	May 22	0.8
February 25	0.5	May 27	0.5
March 4	3.2	June 2	2.0
March 7	0.1	June 5	4.1
March 10	0.2	June 6	0.5
March 13	0.3	June 7	1.9
March 17	0.4	June 11	1.4
March 20	2.1	June 16	0.3
March 21	1.5	June 17	0.4
March 27	1.6	June 22	1.3
March 29	0.1	June 27	4.3

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