CULTURAL STUDIES WITH LEAF LETTUCE

By

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PREFACE

The following study was concerned with several aspects of leaf lettuce culture. The primary objectives were to determine the most productive irrigation method and the most effective means of establishing the crop in the field. A number of cultivars were compared for their tendencies towards premature seedstalk formation (bolting) and for their suitability to commercial production in northeast Oklahoma.

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CHAPTER I

INTRODUCTION

Leaf lettuce (Lactuca sativa, L.), also called looseleaf lettuce, does not form heads, but rather clusters of leaves, and is grown primarily outdoors in home gardens or in greenhouses during the winter (Ryder, 1979). While head lettuce, particularly the crisphead type, is by far the most important commercially grown lettuce in the United States (Whitaker and Ryder, 1974), leaf lettuce may offer more potential for commercial production in Oklahoma for several reasons: (1) Leaf lettuce is not well adapted to long-distance transportation and has a short market life (Seelig, 1970). This should afford an advantage for local production of leaf lettuce compared to long distance shipping from other states such as California, which accounts for about 70% of U.S. lettuce production (Anon., 1983). (2) Leaf lettuce may be grown where the temperature is too high for head lettuce (Thompson and Kelly, 1957). This is an important consideration for Oklahoma where maximum daytime temperatures may exceed 30°C from April to October. The desirable maximum field temperature for head lettuce, as determined by Kimball, Sims and Welch (1967), is about 23°C with a high range of around 28.5°C. (3) Leaf lettuce requires a shorter growing period from planting to harvest than head lettuce (Ryder, 1979), and would therefore, be more suited to the spring and fall growing seasons in Oklahoma which are limited in length due to the extent of the high temperature period.

Leaf lettuce is also significantly more nutritious than head lettuce (Ryder, 1979) and its marketability could be influenced by today's emphasis on health and nutrition.

A successful crop of lettuce requires constant and relatively abundant soil moisture, particularly during the early and late stages of development. Even in areas where rainfall is abundant, supplemental irrigation may be necessary, as extreme fluctuations in soil moisture adversely affect normal crop growth (Whitaker and Ryder, 1974).

Sprinkler, trickle, and subsurface irrigation have been associated with higher yields and water-use efficiencies than conventional furrow irrigation (Sammis, 1980).

Sprinkler systems feature the discharge of water through sprinklers, nozzles, or perforations at high velocitiy (Pair, 1975). Rotating head sprinklers are the most common and include rapidly whirling sprinklers, boom-type sprinklers, and slowly rotating impact-driven sprinklers.

The main advantages offered by sprinkler irrigation are the prevention of salt accumulation near germinating seedlings, rapid and even application of water, higher emergence rates of seedlings, improved soil aggregation, better water-use efficiency, increased yields, and uniform maturity (Whitaker and Ryder, 1974).

Trickle, or drip, irrigation involves the slow application of water under low pressure to soil through mechanical devices or holes called emitters which are located along a water delivery line (Davis, 1975). Trickle irrigation differs from conventional bulk water application irrigation methods in that smaller volumes of water are applied at more frequent intervals, with only a portion of the root zone being wetted (Elfving, 1982).

The principal advantages of trickle irrigation include maximum water use efficiency, low labor and operating costs, the ability to apply fertilizers and other chemicals through the system, added plant protection from diseases and insects by avoiding the wetting of plant leaves, elimination of wind effect on the wetting pattern, and satisfactory use of more saline water. The primary disadvantages are clogging, salinity buildup, and poor soil moisture distribution (Davis, 1975).

Subsurface irrigation is a system which supplies water beneath the soil surface through a buried perforated lateral or lateral with emitters (Goldberg, Gornat and Rimon, 1976). This method wets the root zone of plants and nearly eliminates the evaporation factor.

Successful subsurface irrigation requires favorable soil conditions that permit free lateral movement of water, fairly rapid capillary movement in the root-zone soil, and very slow downward movement in the subsoil (Israelsen and Hansen, 1962). The cost of this type of irrigation system is often prohibitive. Other problems which have limited its widespread use include the difficulties of inspection, maintenance, and repair of equipment, and malfunction of the system due to clogging (Goldberg, Gornat and Rimon, 1976).

Most commercial acreage of lettuce is direct seeded and thinned to the desired stand (Ryder, 1979). Transplants are used in some areas of the United States where the favorable growing period is too short for a successful direct seeded crop. Transplants have the advantages of increasing uniformity, eliminating the need for costly thinning, and reducing field growing time, which allows production for an early market (Whitaker and Ryder, 1974; Ryder, 1979). However, transplanting is generally impractical and uneconomical compared to direct seeding in climatically favorable production areas (Currah, Gray and Thomas, 1974; Whitaker and Ryder, 1974).

Formerly, the accumulation of surface salts on seed beds due to the use of furrow irrigation necessitated the practice of high surplus seeding rates to insure a stand (McCoy, Robinson, Johnson, Curley, Brooks, Giannini and LeBaron, 1969). Consequently, labor costs for thinning amounted to as much as 43 percent of the total labor costs for crop production (Adams and Reed, 1948). The introduction of sprinkler irrigation around 1965 reduced salt accumulation and allowed greatly reduced seeding rates (McCoy et al., 1969; Robinson, 1970). About the same time, labor shortages for thinning and the legal prohibition of the short-handled hoe in California accelerated the adoption of precision planting of lettuce seed (Robinson, Mayberry and Johnson, 1975; Robinson and Mayberry, 1976).

Precision planting was defined by Millier and Sooter (1967, p. 658) as "the continuous, exact placement of one or more seeds in the soil, at a pre-determined depth and spacing, with uniform coverage, and at reasonable planting speeds." Among the advantages of precision planting are reduced thinning costs, reduced competition between young plants, less shock to plants during thinning, an increase in postthinning plant survival, earlier and more uniform maturity, a controlled plant population for maximum yield, and a saving in seed (Zink, 1966; Millier and Sooter, 1967; Inman, 1968).

The singling of seeds prior to their placement in the soil is essential to precision planting. This is a difficult operation with seeds that are small and irregularly shaped, as are those of lettuce. Pelleting, the coating of seeds with inert materials to increase the size and provide a uniform shape, allows the use of precision planting equipment for accurate spacing of seed in the field. However, problems with delayed and reduced total seedling emergence have been associated with pelleted seed (Bishop, 1948; Inman, 1968).

Fluid drilling, the process of sowing pregerminated seed in a gel carrier, improves emergence and crop uniformity (Gray, 1976, 1978; Salter, 1978). The main advantage of fluid drilling over dry seeding is that seeds may be germinated under ideal conditions first and then placed in the soil (Currah, 1978). At present, the fluid drilling technique does not provide accurate spacing of seeds (Ward, 1981), but methods for accurately metering pre-germinated seeds are being investigated (Searcy and Roth, 1982 a, 1982 b; Taylor, Searcy, Motes and Roth, 1981).

Planting lettuce under conditions of high soil temperatures causes much of the seed to become dormant, which in the past has resulted in the practice of using excessively high seeding rates to achieve a commercial stand (Smith, Yen and Lyons, 1968; Ryder, 1979). Planting primed seeds can overcome thermodormancy in lettuce (Guedes and Cantliffe, 1980; Cantliffe, Shuler and Guedes, 1981; Guedes, Cantliffe and Nell, 1981), and thereby reduce the required seeding rates.

Seed primimg refers to the process of soaking the seeds in a specific salt solution for a given period of time at an optimum temperature and then air- or oven-drying them. The primed seed can then be handled in a manner similar to untreated dry seed, often called raw seed, for the purpose of planting. Precision planting of raw seed has been demonstrated under experimental conditions (McCoy et al., 1969) and in commercial situations (Inman, 1968).

Bolting (premature seeding) of lettuce is characterized by elongated seedstalks which reduce market quality. This phenomenon is influenced by various environmental factors, such as temperature and photoperiod, which elicit profoundly different responses in many lettuce cultivars (Thompson and Knott, 1933; Rappaport and Wittwer, 1956; Raleigh, 1959).

Studies with leaf lettuce were conducted with the objectives of:

1. Contrasting the effects of sprinkler, trickle, and subsurface irrigation methods on yield and stand establishment.

2. Evaluating different direct seeding methods with respect to stand establishment and yield potential.

3. Determining the degree to which selected cultivars are susceptible to bolting.

4. Defining cultivars which are most suitable for commercial production under northeast Oklahoma conditions.

CHAPTER II

LITERATURE REVIEW

Irrigation Methods

Sprinkler Irrigation

During the early 1970's irrigation of lettuce in the western part of the United States shifted from near total dependency on furrow irrigation to an emphasis on sprinkler irrigation, particularly for germination and seedling emergence (Whitaker and Ryder, 1974). Sprinkler irrigation is now commonly used to establish the stand.

Robinson (1970) demonstrated that the use of sprinkler irrigation during the entire season allows for a change in bed conformity for lettuce with the subsequent possibility of increasing the plant population per unit area. This offers the potential for large increases in yield without increasing the variability in maturity.

McCoy et al. (1969) reported superior seedling emergence of lettuce under sprinkler irrigation when compared to furrow irrigation. Sprinkler irrigation allowed earlier seedling emergence from coated seed and better stands with both coated and uncoated seeds using reduced seeding rates. The authors proposed that the seeding rate with uncoated seed could be reduced to the theoretical stand (one seed every 12 inches) and give acceptable results if sprinklers were used to aid emergence. Uniformly spaced postthinning stands obtained from coated seed under sprinklers with a three inch seed spacing indicated the feasibility of using mechanical thinning with precision planting. Sprinkler irrigation was also an important factor in obtaining satisfactory lettuce stands using a paired seeding technique (Robinson and Mayberry, 1976).

Moore (1970) suggested that efficient sprinkler irrigation could eliminate much of the water and nitrogen being wasted, especially during the germination period, when using furrow irrigation on lettuce grown on porous soil.

Overhead sprinkling of watercress (Nasturtium officinale R. Br.) during the warm season in Hawaii resulted in increased yield and quality which was attributible to substantially reduced leaf temperature (McHugh and Nishimoto, 1980).

Sprinkler irrigation of muskmelon (Cucumis melo, L.) resulted in a higher salt concentration on the leaves than did furrow or trickle irrigation (Shmueli and Goldberg, 1971 b). Chloride content in the leaves remained high during the entire growing season with sprinkler irrigation.

Trickle Irrigation

When compared to sprinkler irrigation, trickle irrigation shortened the time to emergence and gave a more uniform stand in cucumber (Cucumis sativus, L.), tomato (Lycopersicon esculentum) and pepper (Capsicum annuum, L.) grown in an arid zone, although no differences were noted between the two irrigation treatments for onion (Allium cepa, L.) or muskmelon (Shmueli and Goldberg, 1971 a). The trickle irrigation caused a higher salt concentration in the upper three cm soil layer of the crop row, but this apparently had no effect on emergence, seedling weight, or chloride content of the leaves. In muskmelon, vegetative growth was more rapid and yields were earlier and higher with trickle irrigation than with sprinkler irrigation.

Water savings by trickle irrigation depend primarily on the inefficiency of the system it replaces (Bernstein and Francois, 1973). Drip irrigation of bell pepper required approximately one-third less water than furrow irrigation for maximum yield of the annual crop, and allowed about 50 percent greater yields than either furrow or sprinkler irrigation. Singh and Singh (1978), in a study with four different gourd crops, reported water use efficiency in a hot arid climate to be nearly twice as high as with overhead sprinklers or with furrow irrigation. From their studies the authors concluded that trickle irrigation has the potential to increase the yield of most, if not all, vegetable crops. Bucks, Erie and French (1974) found that trickle irrigation, as well as modified furrow irrigation, reduced irrigation water requirements although not consumptive use for production of cabbage (Brassica oleracea capitata). Trickle irrigation gross requirements for red raspberry (Rubus idaeus, L.) were about 35 percent of the sprinkler water requirements with no difference in yields under the conditions of a study by DeBoer, Peterson and Evers (1983). Tomatoes irrigated with trickle, sprinkler, and furrow methods gave equal yields, but the trickle plots had only about half the water application requirements of the other two methods (Doss, Turner and Evans 1980). Trickle irrigation of potato (Solanum tuberosum) offered higher water use efficiencies than sprinkler or furrow irrigation, although with lettuce, water use efficiencies were comparable for all three methods due to good stand establishment and avoidance of moisture-stress conditions (Sammis, 1980).

Trickle irrigated 'Golden Delicious' apples (Malus domestica, Borkh.) matured earlier and were higher in yellow color, soluble solids and pH than sprinkle irrigated apples (Drake, Proebsting, Mahan and Thompson, 1981). A study comparing trickle irrigation to furrow irrigation of tomatoes showed that higher yields could be obtained under tropical conditions using trickle irrigation, with less water applied and no decline in fruit quality (Lin, Hubbel and Tsou, 1983). Goldberg and Shmueli (1980) reported increased yield, leaf growth and root development of bell pepper grown with trickle irrigation as compared to sprinkler irrigation.

A combination of trickle irrigation and night misting significantly reduced both the incidence and severity of tipburn in field lettuce plants growing in the inner rows of a four row bed system (Cox and Dearman, 1981). The authors proposed that these treatments are effective in maintaining root-pressure flow which translocates calcium ions to heart leaves of lettuce plants, thereby reducing tipburn injury.

In trickle irrigated bell pepper, salts accumulated in the surface soil between the drip orifices and at the perimeter of the wetted zone, thus serving as a potential cause of root injury to the fine roots in the upper 2.5 cm of the soil (Bernstein and Francois, 1973). However, when brackish irrigation water was used larger reductions in yield occurred with sprinkler and furrow irrigated peppers than with trickle irrigation. With trickle irrigated carnations, the upper three cm of the soil profile were observed to be high in soluble salt content, especially midway between adjacent nozzles (Goldberg, Gornat and Bar, 1971).

Kays, Johnson and Jaworski, (1976) demonstrated the potential for multiple cropping of bell pepper and summer squash (Curcurbita pepo var. melopepo) with trickle irrigation under south Georgia conditions. This could allow fixed costs to be defrayed over two crops and consequently increase profit per unit area.

Subsurface Irrigation

Higher yields of potato were reported with subsurface irrigation than with trickle, sprinkler, or furrow irrigation (Sammis, 1980). Lettuce yields were comparable with all three irrigation methods. Water use efficiency with subsurface irrigation of potato was higher than that with sprinkler or furrow irrigation, and comparable to trickle. No significant differences were noted among the four irrigation techniques when evaluating water use efficiencies with lettuce.

Stand Establishment

Coated Seed

Studies with head lettuce by Zink (1966) showed that heavy prethinning stand densities caused stunting of prethinned plants, decreased postthinning plant survival, delayed maturation, and decreased harvest density (the number of plants suitable for harvest at any one time) and yield. Delayed thinning of heavy stands caused an additional decrease in postthinning plant growth, whereas delayed thinning of light stands showed no significant reduction in prethinning or postthinning plant growth, harvest density, or total yield. Semiprecision planting of coated seed and reduced rates of seeding increased the total yield and the harvest density. Light stands, made possible by more precise planting, allow more leeway in thinning date and are essential for mechanized lettuce thinning.

Earlier work by the same researcher (Zink, 1955) demonstrated a significant reduction in the time required to thin lettuce plants grown from pelleted seed versus those grown from nonpelleted seed, with no effect on the spacing between plants. Robinson, Mayberry and Johnson (1975) were able to obtain adequate stands of lettuce using a number of types of coated seed. They observed differences in the performance of specific coatings under different irrigation methods.

Comparing the performance of lettuce seed with seven different coatings to raw seed, Roos and Moore (1975) observed that coated seed emerged one to two days later than raw seed and gave lower seedling weights, but nevertheless allowed precision planting of lettuce with no apparent sacrifice in overall performance of emergence. In most instances the total emergence and coefficient of variability of plant weights at 20 days were equal for the two treatments. Zink (1955) observed a significant reduction in total plant emergence and a significant delay in the rate of emergence with pelleted lettuce seed in field trials. Temperatures of 22°C and higher caused a significant reduction in germination of pelleted seed.

Experimenting with tomato, lettuce, and onion seed, Bishop (1948) obtained a slightly slower germination rate from pelleted seed than from uncoated seed in cold-frame and field tests. The pelleted seeds also gave lower germination percentages in standard laboratory germination tests. Tests indicated that the pelleting process did not harm the seed and that the differences in germination between coated and uncoated seed were due to the physical properties of the clay coating itself.

Millier and Sooter (1967) concluded, based on their own as well as earlier findings, that the clay coating of commercially pelleted seeds inhibits both the rate of emergence and total emergence of carrot, lettuce, onion, tomato, and sugar beet seed, by reducing the amount of oxygen that gets to the seed. They suggested that cracking the coating of pelleted carrot, onion, tomato, and sugar beet seeds with steel rolls, after they have been singled and prior to placement in the furrow, can increase the percentage and rate of seedling emergence. For fragile seeds such as lettuce, seed pellet coatings made of sand and sugar solutions were proposed, as they are porous and disintegrate rapidly when in contact with soil moisture, and thus do not impede germination. Sachs, Cantliffe and Nell (1981) attributed the inhibitory effect of pellet-coating on the germination of sweet pepper to the physical properties of the coating materials, and recommended pellet coatings which would allow more oxygen to the imbibing seed in order to assure adequate germination.

Sharples (1981) was able to obtain faster, more complete, and more uniform seedling emergence from pelleted lettuce seed containing a granular activated carbon layer adjacent to the seed and overcoated with standard coating materials, than from ordinary pelleted seed. The granular carbon layer evidently allowed unobstructed oxygen diffusion and adsorbed exuded endogenous growth inhibitors. The author pointed out that the costs of manufacturing such seed may limit its commercial potential.

Another approach to improving the germination of pelleted seed is to reduce the amount of coating material. Trials in the Salinas Valley in California showed that seedling emergence from fully coated lettuce seed, with a weight ratio of 50 to 60 parts coating material to one part seed, was slower than that from uncoated seed (Inman, 1968). Coated seeds with ratios of 5:1 and 10:1 gave intermediate emergence rates. The 10:1 pelleted seed is commercially available and is known as minimum-coated seed. Tests indicated that it is possible to achieve stands with about 10 percent double plantings using minimum-coated lettuce seed with the John Deere Hansen planter or the English-built Stanhay planter (Inman, 1968).

Spherical-coated celery (Apium graveolens var. dulce) seed, with a coating ratio of about 40:1, gave a significantly lower yield than uncoated seed (Zink, 1967). Minimum-coated celery seed (10:1) gave a comparable emergence percentage to uncoated seed and a slightly greater yield in the 2-dozen- and 2 1/2-dozen-size pack as compared to uncoated seed. In the study, precision planting with coated seed simplified thinning, nearly eliminating finger-thinning, and showed that about 25 man-hours of thinning labor per acre could be saved with this technique, possibly more with mechanical thinners.

There are apparently no inherent problems associated with the storage of pelleted lettuce seed under favorable storage conditions. In a study by Roos (1979), both pelleted and uncoated lettuce seed retained full viability for three years. The coated lettuce seed was, however, found to deteriorate more rapidly than uncoated seed under poor storage conditions.

Fluid Drilling

Currah, Gray and Thomas (1974) demonstrated that establishment of vegetable crops could be improved by sowing pregerminated seeds with a fluid drill. Seedling emergence from imbibed lettuce seeds sown with the fluid drill was more synchronous than that from dry seed. In one of two experiments the length of the emergence period was decreased by 50 percent with seeds imbibed for 24 hours and sown in a gel, compared to lettuce grown from dry seed. Seedlings from carrot seeds imbibed or germinated, then sown in a gel, emerged five days earlier than from dry seeds and gave higher yields after 64 days. Celery seeds germinated and sown in a gel gave a 60 percent stand compared to a two percent stand from dry seed.

Sowing pregerminated lettuce seeds with a fluid drill significantly reduced the variability of both emergence and maturity and gave earlier emergence and greater total emergence than size-graded conventionally sown untreated seed (Gray, 1976, 1978). Other experiments indicate that sowing germinated seeds or seeds imbibed to the point of radical emergence is an effective technique for preventing thermodormancy (Gray, 1977).

Salter (1978) compared pregerminated fluid drilled lettuce seed with dry seed and found that in all 28 comparative sowings seedlings emerged and matured earlier by as much as eight days with the fluid drill method. Fluid drilled seeds also provided a higher emergence percentage in 24 of the 28 sowings, as well as a more synchronous emergence resulting in more uniformly maturing crops at harvest. Tests with fluid drilled and conventionally sown seeds of carrot, celery, onion, parsnip, and tomato showed that fluid drilling resulted in earlier emergence in all crops, greater percentage emergence in carrot, celery, parsnip, and tomato, increased yields in celery, onion, and tomato, higher earlier yields in carrot and parsnip, and earlier maturity in tomato.

Seedling emergence in warm (>25°C) soils was more rapid from imbibed lettuce seed or dry seed sown in a gel than from untreated seed (Hemphill, 1982), and also increased mean head weight at harvest and reduced head weight variability. Combining imbibition and gel gave more rapid emergence than either treatment alone and gave comparable results to transplanting in reducing head size variability. It was suggested by the author that the technique of gel- sowing lettuce seed imbibed at nonstressing temperatures could be used to overcome poor germination due to seedbed crusting or high temperatures.

In an experiment testing different seeding methods for establishing glasshouse lettuce in peat blocks, sowing pregerminated seeds gave slightly higher seedling emergence percentages than pelleted or dry seeds (Chrimes and Gray, 1982). Emergence was invariably earlier from pregerminated seeds than from pelleted or dry seeds. The use of gels reduced emergence. Gray (1978) also reported that an increase in the rate of gel carrier progressively reduced the percentage of emergence from lettuce seed, and proposed that when fluid drilling lettuce seed the rate of gel be held to the lowest consistent with accurate delivery of the seeds, which in the author's experiments was 20 ml per meter of row.

Primed Seed

High temperatures inhibit the germination of lettuce seed (Borthwick and Robbins, 1928). The authors reported a decrease in the germination percentage of most varieties at temperatures between 25 and 30°C, and almost total inhibition of germination at 30°C, probably as a result of restricted gas exchange through the endosperm and integumentary membranes. Sharples (1973) noted that at a constant temperature of 35°C germination of lettuce seed usually does not occur. Gray (1975) showed that a few hours exposure of lettuce seeds to high temperatures during critical stages of germination inhibited germination. High temperatures which inhibit germination may lower the maximum temperature at which germination can subsequently occur, especially for seeds held in the dark (Heydecker and Joshua, 1976).

Experiments by Smith, Yen and Lyons (1968) indicated that inhibition of lettuce seed germination is reversible and suggested that high temperature probably prevents radicle protrusion but does not inhibit other stages of seedling growth. Untreated seeds of the cultivar 'Prima Verde' germinated nearly 100 percent at 35°C after being held at a lower temperature (25°C) on moist filter paper for a minimum of 24 hours, indicating that germination had proceeded to a stage unaffected by high temperature.

Thermodormancy may be overcome with proper primimg techniques (Guedes and Cantliffe, 1980). Priming seeds of lettuce cultivars 'Minetto', 'Ithaca' and 'Mesa 659' in 1% K_3PO_4 solution for nine hours at 15°C gave significantly higher germination percentages and rates than seeds soaked in water when both were incubated at 35°C.

Germination of untreated seeds was almost completely inhibited at 35°C. In experiments by Guedes et al. (1981), nonprimed 'Minetto' lettuce seeds failed to germinate at 35°C unless imbibed in water for at least six hours at 20°C prior to sowing. Maximum germination of unprimed seeds at 35°C required 15 to 16 hours imbibition at 20°C. About 60 percent of seeds primed in 1% K_3PO_4 at 15°C for nine hours germinated at 35°C. Maximum germination (about 85 percent) of primed seeds occurred after seeds were held at 20°C for nine hours before incubation at 35°C. It was concluded that the optimum time for priming lettuce seed at 15°C in 1% K_3PO_4 in order to overcome thermodormancy is nine hours. This permits loosening of the endosperm membrane, potentially improving seed germination at high temperatures, without causing rupture of the membrane.

Primed 'Valmaine' lettuce seeds gave more uniform stands, earlier emergence, and earlier and more uniform maturity than unprimed seeds when planted in the field under moderately stressful soil temperatures, with day temperatures ranging from 30 to 33°C, and night temperatures from 22 to 26°C (Cantliffe, Shuler and Guedes, 1981). The authors proposed that, compared to unprimed seeds, plant stands could be doubled and days to harvest reduced under conditions of only moderate soil temperature stress by planting 'Valmaine' lettuce seed primed for nine hours in 1% K_3PO_4 at 15°C in the dark.

Treatments with kinetin, thiourea, and combinations of kinetin and ethephon have also shown an effect on overcoming thermodormancy in lettuce seed (Smith, Yen and Lyons, 1968; Thompson and Horn, 1944; Sharples, 1973).

Causes of Premature Seeding (Bolting)

In head lettuce the failure to form solid heads and the shooting of seed stalks may be influenced by various environmental factors, as reported by Thompson and Knott (1933). High temperature appeared to be a factor in causing premature seeding of lettuce, according to their experiments. They also suggested that high temperatures during the early stages of growth are largely responsible for the formation of seed stalks later in the season.

Rappaport and Wittwer (1956) reported that night temperatures above 18°C caused flowering of non-vernalized 'Great Lakes' head lettuce plants. In seedlings vernalized in excess of 13 days at 4.4°C, flowering was promoted by a combination of high air and root temperatures and long days. Raleigh (1959) proposed that seedstalk elongation in '456' lettuce is primarily influenced by night temperatures. He suggested that if night temperatures are cool, undue seedstalk elongation will not occur even when the daytime temperatures are in the higher range for lettuce production in upstate New York.

The rate of seedstalk formation differs according to cultivar (Ryder, 1979). Some cultivars, such as 'Grand Rapids,' are long-day plants while others, such as 'Great Lakes,' are day-neutral plants. Rappaport and Wittwer (1956) demonstrated the importance of temperature in combination with photoperiod in promoting flower induction and seedstalk elongation of three cultivars of lettuce. Flower induction in 'Tendergreen' and 'Bibb' was controlled by long days, while the rate of subsequent seedstalk development depended on both photoperiod and night temperature. With 'Grand Rapids' both flower induction and seedstalk elongation were governed by temperature and photoperiod.

CHAPTER III

MATERIALS AND METHODS

Studies with leaf lettuce were conducted at the Oklahoma State University Research Station in Bixby, Oklahoma during the spring and fall growing seasons of 1983 and 1984. The soil at the station is a very fine sandy loam with a slope of 0-1%. Soil test pH was 6.2. Water used for irrigation was well water with an electrical conductivity of 660 mmhos/cm, a total soluble salts content of 436 ppm, a sodium adsorption ratio of 0.5, a sodium percentage of 13%, and a pH of 8.2. The water was classified by the Oklahoma State University Water and Soil Salinity Laboratory as being of excellent quality for irrigation on all types of soils with all types of crops.

Plots for spring 1983 trials were uniformly fertilized prior to planting, with 56 kg N/ha, 25 kg P/ha, and 93 kg K/ha, on February 28, 1983. Plots used for spring 1984 trials were fertilized on March 2, 1984 with 44 kg N/ha, 36 kg P/ha, and 19 kg K/ha. In both years, immediately following fertilization, 50% diazanon soil insecticide was sprayed and incorporated into the soil at the rate of 4.5 kg AI/ha. Plots used for fall trials in 1983 and 1984 were fertilized with 56 kg N/ha prior to planting. For weed control, a preplant application of pronamide was incorporated at the rate of 2.8 kg AI/ha in spring 1983 trials, and 1.7 kg AI/ha in fall 1983, and spring and fall 1984 trials.

Transplants used were grown from seed in 080A Todd Planter flats in the Oklahoma State University Horticulture greenhouses in Stillwater. The seedlings were grown in 'Redi-Earth' soilless mix and fertilized two weeks after emergence with soluble 20-10-20 fertilizer at the rate of 300 mg/l N, 66 mg/l P, and 249 mg/l K.

Experiments

Irrigation Trials

The objective of these experiments was to evaluate the effect of different irrigation methods on the growth and yields of leaf lettuce.

Three irrigation methods were employed: sprinkler, trickle, and subsurface. Each treatment was replicated three times in a split plot design. Plots were 7.3 m long by 2.1 m wide. Each plot contained six rows spaced 35 cm apart.

Irrigation was supplied to sprinkler irrigation plots by Rainbird PJAD-TNT impact sprinklers, each with a single 3.2 mm (1/8") nozzle and an output of 11.4 l/min (three gpm) at 27.6 N/cm^2 (40 psi). Four sprinklers were used per plot. One sprinkler was set in each of the corners of an 11 m square surrounding the plot, and fixed to rotate 90 degrees. This provided 2.3 cm/hr of irrigation water at the pressure indicated above.

Trickle and subsurface irrigation plots were irrigated via Submatic 9.5 mm polyethylene hose equipped with E2 emitters spaced at 61 cm intervals. Each emitter had a 0.05 mm orifice with an output of 7.6 l/hr at 6.9 N/cm^2. Each plot contained three emitter lines spaced 70 cm apart and located between rows 1-2, 3-4, and 5-6. Emitter output during actual operation tested at 6.0 l/hr, which provided an average of 1.4 cm/hr of irrigation water over the plot area. Emitter lines were placed on the surface of trickle plots and buried 15 cm deep in subsurface irrigated plots. Prior to entry in the emitter lines, water was acidified to pH 6.7 to inhibit the formation of Fe precipitates and filtered through a Submatic FTP20 filter with a C100M cartridge in order to prevent clogging.

Irrometer Model R tensiometers were installed in the plots for the purpose of measuring soil moisture conditions. The use of tensiometers in controlling drip irrigation applications has been shown to improve water use efficiency and increase yields of some fruit and vegetable crops (Klein, 1983; Van der Veken, Michels, Feyen and Benoit, 1982). Tensiometers were set at a depth of 20 cm below the soil surface in the initial experiment and at a depth of 15 cm in subsequent trials. Difficulties were, however, encountered in applying tensiometer readings at those depths to the actual soil moisture conditions in the uppermost portion of the soil profile which is of particular importance to shallow- rooted crops such as lettuce, especially during the early phases of growth. Irrigation applications were therefore made according to apparent crop needs.

Trial - Spring 1983. Seedlings of the cultivars 'Waldmann's Green' and 'Deep Red,' from seed sown March 1, 1983, were transplanted at 35 cm in-row spacing on March 25. Each cultivar occupied three rows on either half of the plot. The middle row of each cultivar was used for data, the other rows serving as guard rows. The transplants were not watered in as the soil was alrady rather wet at the time of transplanting.

Plots were sidedressed with 28 kg N/ha on April 26. Pesticide applications of thiodan, malathion, and Bacillus thuringiensis were made on May 4, 8, and 22, respectively. Sprinkler plots were irrigated for 90 minutes on May 10. Trickle and subsurface irrigation plots received irrigation applications for 60 minutes on May 6, 30 minutes on May 7, 8, and 9, and 35 minutes May 10. All plants from the data rows, except for the end plants in each row, were harvested on May 26, and fresh weights recorded. Plants were then trimmed to marketable quality by removing damaged and discolored leaves, and reweighed. Dry weights were determined from random samples of five plants from each data row.

Trial II - Spring 1983. Following harvest of the first crop, a second trial was carried out utilizing the same plots in an attempt to obtain a double crop on the same land during the spring growing season. Experimental procedures were the same as for Trial I.

An additional preplant application of pronamide herbicide, at 0.84 kg AI/ha, was made. Plots received 56 kg N/ha prior to planting. Seedlings from seed sown April 28 were transplanted on June 2. Trickle and subsurface irrigation plots were irrigated for 30 minutes on June 15 and 30, and for 45 minutes on June 22 and 24. No sprinkler irrigation applications were made. Plants were treated with pydrin insecticide on June 17.

Plants began to exhibit symptoms of bolting and data plants were harvested July 5. Only fresh untrimmed weights were recorded.

Trial III - Fall 1983. An experiment identical to the spring trials in design and general procedures was conducted in the fall. Transplants from seed sown August 16 were put into the field September 9, and watered in for 90 minutes in the sprinkler plots and 45 minutes in the trickle and subsurface irrigation plots. Problems with transplant survival were encountered due to high temperatures (average maximum daily temperature the first five days following transplanting was 36.6°C) and desiccating winds. Replacement seedlings were transplanted on September 19, but were only sufficient to maintain two of the three replications.

Plots received 28 kg N/ha as a sidedressing on October 13. Pesticide treatments of thiodan, pydrin, and Bacillus thuringiensis were applied September 22 and 27, and October 10, respectively. Subsurface and trickle plots were irrigated for 30 minutes on September 19 and 27, for 45 minutes on September 29, and for 60 minutes on October 2. Sprinkler irrigation was not applied.

Data plants were harvested October 28 after the crop began to bolt prematurely.

Stand Establishment Trial

An experiment was set up at Genoff's commercial vegetable farm in Bixby, Oklahoma, in order to test the effects of different seeding techniques on emergence and stand establishment. The farm is located adjacent to the Oklahoma State University Research Station, and has a sandy loam type soil. Seeding methods involved sowing raw, pelleted, and fluid drilled pregerminated seed. Each treatment was replicated four times in a randomized block design. Rows were 7.62 m long and between-row spacing was 38.1 cm.

Raw seed was sown with a Planet Jr. Model 300 A row unit planter equipped with a #4 hole plate. Pelleted seed was planted with a tractor-mounted Stanhay precision planter, which was set to drop a single pellet every 19 cm. Pelleted seed used was Moran mini-coated seed with a coating to seed ratio of 10:1. Fluid drilled seed was pregerminated to the point of radicle emergence in bubbling water columns before being dispersed in fluid gel at the rate of 0.5 g of seed per liter of gel. Gel mixture consisted of 19 g Laponite 508 plus 0.1 g captan per liter of water. Fluid drilling was done with a modified Planet Jr. Model 300 A planter, as described by Spinks, Roth and Motes (1979). The fluid gel mixture was extruded at the rate of 30 ml/m of row.

Trial IV - Fall 1983. Planting was carried out on September 2, using a single cultivar, 'Waldmann's Green'. Seeds for fluid drilling had been pregerminated in the water columns overnight, for 12 hours, then refrigerated for six hours in Petri dishes before being mixed in gel for planting.

All seeding in this trial, as well as in subsequent trials, was done as shallow as possible, since it has been shown that sowing lettuce seed deeper than 1.8 cm below the soil surface delays emergence (Zahara, 1969). The field was irrigated immediately after planting, and thereafter as required, by means of sideroll sprinklers.

Emergence counts were made September 19. The experiment was terminated at this point since stands were totally inadequate, although laboratory tests showed the seed to be viable.

Irrigation/Stand Establishment Trials

The purpose of these experiments was to evaluate the effect of irrigation methods on growth, yield, and seedling emergence of a direct seeded lettuce crop. Different precision seeding methods were compared for their effects on emergence rates, postthinning stand counts, and yield.

Sprinkler and trickle irrigation treatments were used, and were identical to those used in the 1983 irrigation trials. Subsurface irrigation was not used, but was replaced in these trials by control (nonirrigated) plots. Treatments, including the control, were replicated three times in a split plot design. Plots were 7.5 m long by 2.1 m wide, with six rows per plot spaced 35 cm apart. Subtreatments within each plot consisted of four kinds of direct seeding: raw (untreated), pelleted, fluid drilled pregerminated, and primed.

The pelleted seed used was Moran mini-coated. Pelleted and raw seed were sown with a handpush Stanhay S870 Precision Drill planter. For planting raw seed, the components of the seed metering unit of the planter were made up of a T choke, A-2 springbase, and a plain thin belt with six holes of 4.0 mm diameter, which allowed an average of two to three seeds to be dropped every 30.5 cm. With pelleted seed, an A choke, A-2 springbase, and a plain rubber/canvas laminated belt with six holes of 5.2 mm were used. This combination permitted the planter to space three to four seeds every 30.5 cm. It was initially planned to use a belt with six groups of three closely spaced holes, which would dispense three seeds approximately 2.5 cm apart, at 30.5 cm intervals. Unfortunately, difficulties were encountered in obtaining the correct belts.

Seeds for fluid drilling were pregerminated to the point of radicle emergence, then suspended in Laponite 508 gel (19 g/l H_2O + 0.1 g captan) at the rate of 0.5 g seed per liter of gel. The gel mixture was planted with the Planet Jr. Model 300 A planter modified for fluid drilling, and was extruded at the rate of 30 ml per meter of row length.

Primed seed was prepared by incubating the seeds in a 0.2 molal NaCl solution in the dark for 47 hours at 28°C. The seeds were then air dried after a brief rinse in cool running tap water. In the laboratory, this procedure allowed for nearly 100 percent germination of a sample of 50 seeds which were incubated in the dark in water at 30°C for 13 hours. Untreated seeds required 24 hours to achieve nearly 100 percent germination. Primed seeds were planted in exactly the same manner as raw seeds.

Trial V - Spring 1984. Seeds of the cultivar 'Waldmann's Green' were sown April 6, using the four seeding methods described. The inner four rows of each plot were data rows. The outer row on either side of each plot was a guard row and was sown with raw seed of the same cultivar, using the Stanhay planter.

Fluid drilled seeds had been pregerminated in water columns for 12 hours and then refrigerated in Petri dishes for nine hours before planting. The radicles were less than two mm in length at this time.

Emergence counts were made over the entire length of each data row on April 16, 19, and 23, and on May 1. Plants were thinned to the desired in-row spacing of 30.5 cm on May 1, and final plant stands were noted.

Plots were sidedressed with 28 kg N/ha May 16. Bacillus thuringiensis was sprayed on plants May 21. Sprinkler irrigation operated for two hours on May 16, and trickle irrigation was applied for 30 minutes on May 10, 18, 21, and 25, and on June 4, for 45 minutes on May 13 and 23, and for 60 minutes on May 16.

Plants were harvested June 6, and fresh trimmed weights recorded.

Trial VI - Fall 1984. This experiment was intended to be a repeat of Trial V. Plots were seeded September 7. For fluid drilling Natrosol 250 HHR (16 g/l H_2O + 0.1 g captan) was used in place of Laponite 508. Sprinkler and trickle plots were irrigated immediately after seeding and again on Septemebr 14. Only a very few plants had emerged in any of the rows by September 25, so the experiment was discontinued.

Variety/Stand Establishment Trials

The objectives of these trials were to compare the effects of various stand establishment methods on the yields of selected leaf lettuce cultivars and to compare, for each of those cultivars, seedling emergence and final stands as affected by the type of seeding technique employed.

Stands were established with transplants and with two seeding methods: fluid drilling of pregerminated seed and precision drilling of raw seed. Fluid drilled seeds were planted with a Planet Jr. Model 300 A planter and raw seeds with a Stanhay S870 planter, as previously described.

The design was a randomized block design with two replications. Ten cultivars were tested. In each replication, stand establishment treatments and cultivars were randomized over two tiers, each containing 19 rows. Rows were 5.6 m long and spaced 35 cm apart.

Irrigation was applied by sprinkler as needed, but was not considered a variable in these trials.

Trial VII -Spring 1984. Seedlings from seed sown March 15 were transplanted April 16. Plants were spaced 35 cm apart within rows. Fluid drilled and raw seed were also planted on April 16. Fluid drilled seeds had been pregerminated in water columns for 12 hours, then refrigerated for 10 to 11 hours before being mixed in Laponite 508 gel for planting. As a check, a sample of 50 seeds of each cultivar was examined for radicle emergence prior to fluid drilling.

Cultivar selection consisted of the following: 'Deep Red,' 'Prizehead,' 'Redhead,' 'Red Salad Bowl,' 'Ruby,' 'Grand Rapids T.B.R.,' 'Green Ice,' 'Salad Bowl,' 'Slobolt,' and 'Waldmann's Green.'

In seeded rows, emergence counts were made on April 13, 16, 19, and 23, and on May 1. Plants were thinned to the desired spacing of 30.5 cm on May 1.

Sidedressings of 28 kg N/ha were applied to the transplants on April 20 and on May 8, and to seeded plants on May 16. The entire crop was irrigated for two hours, at a rate of about 2.5 cm per hour, on May 21. Plants were treated with *Bacillus thuringiensis* May 21.

All transplanted and seeded data rows were harvested May 29. The fresh trimmed weights were taken.

Trial VIII - Fall 1984. Fluid drilled and raw seeded rows were planted September 7, then irrigated. Fluid drilled seeds were sown in Natrosol 250 HHR, after pregermination in water columns for 12 hours and eight to nine hours refrigerated storage. Pregerminated seeds were sampled for percent germination by observing radicle emergence. Transplants, from seed sown August 15, were planted September 14 and then irrigated. The same 10 cultivars as in Trial VII were used with the exception of 'Slobolt,' which was replaced, due to problems with inadequate germination, by 'Black Seeded Simpson.'

Experimentation with the direct seeded lettuce was discontinued when sufficient stands had not been obtained by September 25. Transplants were sidedressed with 38 kg N/ha on October 8, and treated with malathion October 11. Transplanted data row plants were harvested November 6, and the fresh trimmed weights recorded.

Bolting Trials

The objective of the bolting trials was to examine potential differences in the tendency towards early bolting among several cultivars of leaf lettuce. Ten cultivars were used as treatments, and were replicated three times in a randomized block design. Rows were 5.25 m long and spaced 35 cm apart. Stands were established from transplants spaced 35 cm apart in the row. Plants were sprinkler irrigated as required.

Plants were observed frequently for signs of bolting. The dates on which bolting was observed and the number of plants bolted in each row were recorded.

Trial IX -Spring 1984. The following cultivars were used in this trial: 'Deep Red,' 'Prizehead,' 'Redhead,' 'Red Salad Bowl,' 'Ruby,' 'Grand Rapids T.B.R.,' 'Green Ice,' 'Salad Bowl,' 'Waldmann's Green,' and 'Black Seeded Simpson.'

Plants started from seed March 12 were transplanted in the field April 6. The plants were sidedressed with 28 kg N/ha on April 20 and on May 8. On May 21, irrigation was applied and plants were sprayed with *Bacillus thuringiensis*.

In one of the three replications the fresh trimmed weight was taken from each cultivar as it approached maturity, as an indication of potential plant weight prior to bolting. 'Black Seeded Simpson' was harvested May 16, after one plant was observed bolting. Other cultivars were harvested May 25. Bolting observations in the other two replications were made until May 29.

Trial X - Fall 1984. The same ten cultivars as in the spring bolting trial were planted on September 14 from seedlings started from seed August 15. Plants were sidedressed with 38 kg N/ha on October 8, and sprayed with malathion on October 11. Plants were irrigated September 14, 19, and 24, and October 8.

All three replications were used for bolting observations. Plant weights at optimum maturity were measured in the adjacent variety/stand establishment trial (Trial VIII). Observations for bolting were continued until November 14.

CHAPTER IV

RESULTS AND DISCUSSION

Irrigation Trials

Trial I -Spring 1983

In this experiment the type of irrigation method used, sprinkler, trickle or subsurface, had no significant effect on the mean yields of the cultivars 'Waldmann's Green' and 'Deep Red,' when analyzing total fresh trimmed weight, marketable weight, and mean fresh plant weight[1] (Table I). Total fresh weights before trimming ranged from 2.76 to 2.83 kg/m^2 depending on the irrigation treatment applied, and were not significantly different. Contrast analyses between sprinkler and drip (trickle and subsurface) irrigation, and between trickle and subsurface irrigation proved to be nonsignificant for all yield parameters.

Sprinkler plots received a total of 3.4 cm irrigation water, and trickle and subsurface plots 4.2 cm each. Rainfall during the growing period was 24.2 cm. Water use efficiency (marketable yield per amount of irrigation water applied) was higher with sprinkler irrigation, but this may not be an entirely correct assessment owing to the marginal

[1]In all trials, marketable plants were those which weighed at least 250 g since, according to commercial lettuce growers in Oklahoma, this is the minimum weight preferred by buyers.

TABLE I

THE EFFECT OF IRRIGATION METHODS ON YIELDS OF 'WALDMANN'S GREEN' AND 'DEEP RED' LEAF LETTUCE

Variable	Fresh weight[z] (kg/m^2) Total	Fresh weight[z] (kg/m^2) Marketable	Mean fresh weight per plant (g)	Percent marketable plants
Irrigation method				
Trickle	2.25ns[y]	1.67ns	274ns	57.4[w]
Sprinkler	2.15	1.66	274	58.3
Subsurface	2.14	1.58	257	58.3
Cultivar				
Waldmann's Green	2.38ns[x]	2.06*	297*	69.1[w]
Deep Red	1.98	1.22	240	46.9

[z]All weights taken afte trimming.

[y]Differences among irrigation method means in each column nonsignificant at 5% level.

[x]ns,*: Differences between cultivar means in each column nonsignificant, or significant at 5% level.

[w]Irrigation method x cultivar interaction significant at 5% level.

difference (0.8 cm) in water application amounts between treatments.

'Waldmann's Green' produced significantly higher marketable yield and heavier mean fresh plant weight than 'Deep Red,' averaged over the three irrigation treatments (Table I). The total fresh pretrimmed yield of 'Waldmann's Green' was 3.02 kg/m^2 compared to 2.56 kg/m^2 for 'Deep Red,' but the difference was nonsignificant at the 5% level.

An irrigation treatment by cultivar interaction, significant at the 5% level, occurred in the analysis of percent marketable plants (Table I). This resulted from 'Waldmann's Green' having a higher percentage of marketable plants than 'Deep Red' with trickle or subsurface irrigation, while with sprinkler irrigation 'Deep Red' had the greater percentage of marketable plants. There was little difference among irrigation treatments with respect to percent marketable plants. Averaged over the irrigation treatments, 'Waldmann's Green' showed a much higher percentage of marketable plants than did 'Deep Red.'

The percent dry weight (dry weight x 100/fresh weight), taken from samples of trimmed plants, did not differ significantly among irrigation treatments or between cultivars. The mean percent dry weight was 7.62% for 'Waldmann's Green' and 6.95% for 'Deep Red.'

The crop required 62 days to reach maturity from transplanting. Growth was delayed by cool soil temperatures during the month of April when the average daily maximum temperature was 13.9°C and the average daily minimum temperature 6.7°C.

Trial II - Spring 1983

Plants in this trial bolted prematurely and were not of suitable size or quality for making yield comparisons. The mean fresh untrimmed plant weight, from plants harvested 33 days after transplanting, was 156 g. Long daylengths and high day and night temperatures during the growing period, from June 2 to July 5, were favorable to bolting (Raleigh, 1959; Rappaport and Wittwer, 1956). The average daily maximum and minimum temperatures during the last half of June were 32.3°C and 19.2°C, respectively, and during the first four days of July 35.0°C and 21.9°C, respectively.

Trial III - Fall 1983

Again, plants bolted prematurely, and were removed from the field after 49 days. The mean fresh untrimmed plant was 166 g. Unfavorably high temperatures during the early stages of growth may have contributed to premature seedstalk formation (Thompson and Knott, 1933). The average daily maximum and minimum temperatures during the first five days following transplanting, September 9-13, were 35.6°C and 19.4°C, respectively.

Stand Establishment Trial

Trial IV - Fall 1983

This experiment was terminated early because seedling emergence, as late as 17 days after sowing, was too low to expect a reasonable stand to be obtained. The mean number of seedlings per meter of row length was 5.3 from raw seed, but only 0.5 from pelleted seed and 1.6 from fluid drilled pregerminated seed. High soil temperatures were probably responsible, directly or indirectly, for the poor emergence. The average daily maximum soil temperature for the first 12 days after sowing, September 2-13, was 36.1°C. In the case of raw and pelleted seed, this temperature could have been sufficiently high to inhibit germination (Sharples, 1973; Gray, 1975). In addition, the soil temperature, as recorded by the National Oceanic and Atmospheric Administration, was measured at a depth of 10 cm, and was undoubtedly much higher closer to the soil surface where the lettuce seed was sown. However, the poor emergence from pregerminated seed suggests that the problem was more likely due to seedling blight (damping-off) caused by pathogenic fungi.

Both the research station at Bixby and the Genoff farm have been used for vegetable production for many years, a situation favorable to the buildup of soil pathogens, and problems associated with fungal diseases of seedlings have been previously encountered in other experiments at the station. The two species of fungi responsible for most losses in commercial plantings, *Pythium debaryanum* and *Rhizoctonia solani*, both thrive in warm soil (Roberts and Boothroyd, 1972).

Irrigation/Stand Establishment Trials

Trial V - Spring 1984

From tests with a single cultivar, 'Waldmann's Green,' irrigated plots produced significantly higher total fresh weight, marketable weight, mean fresh plant weight, and percent marketable plants than nonirrigated control plots (Table II).

Within the irrigation treatments, trickle irrigation gave significantly greater total weight and marketable weight than did sprinkler irrigation. Mean fresh plant weight and the percent marketable plants tended to be greater with trickle than with sprinkler

TABLE II

THE EFFECT OF IRRIGATION AND DIRECT SEEDING METHODS ON THE YIELD OF 'WALDMANN'S GREEN' LEAF LETTUCE

Variable	Fresh weight[z] (kg/m^2) Total	Fresh weight[z] (kg/m^2) Marketable	Mean fresh weight per plant (g)	Percent marketable plants
Irrigation method				
Trickle	1.53	0.84	211	36.6
Sprinkler	1.25	0.57	192	27.7
Control (nonirrigated)	1.01	0.31	153	14.9
Contrast				
Irrigation vs control	**[y]	**	*	**
Trickle vs sprinkler	*	**	ns	ns
Seeding method				
Fluid drilled	1.36ns[x]	0.63ns	184ns	28.5ns
Pelleted	1.29	0.61	179	25.5
Primed	1.21	0.61	204	30.0
Raw seed	1.20	0.48	175	21.6

[z]All weights taken after trimming.

[y]ns,*,**: Contrasts nonsignificant, significant at 5% (*) or 1% (**) level.

[x]Differences among seeding method means in each column nonsignificant at 5% level.

irrigation, although the differences were not significant at the 5% level (Table II). However, the total amount of water applied by each irrigation treatment differed, and it is therefore difficult to know how much of the yield differences to attribute to the method of application and how much to the amount of irrigation water applied. Yields appeared to increase with higher irrigation water applications (Figure 1). The total amount of irrigation water applied was 7.1 cm to trickle plots and 4.5 cm to sprinkler plots. Rainfall during the growth of the crop amounted to 18.4 cm.

Sprinkler plots received less irrigation water than trickle plots due to the nature of the water application methods. Trickle irrigation has lower labor and operating costs and may therefore be applied more frequently in lesser amounts than sprinkler irrigation (Davis, 1975). The majority of trickle irrigation applications made in this experiment amounted to 0.7 cm of water per application. For crops, such as lettuce, with an effective root depth of about 30 cm and grown on a sandy loam soil, the recommended water application per irrigation by the sprinkler method is 2.2 cm (Pair, 1975). Because of frequent, light to moderate rainfall during the growing period in this experiment, it was not considered expedient to apply such large amounts of irrigation water very often. For much the same reasons, sprinkler irrigation was not used in Trials II and III.

Water use efficiency was about eight percent higher with sprinkler irrigation than with trickle irrigation.

Seeding methods had no significant effect on yield (Table II), but did have some effect on early emergence and final postthinned stand (Table III). Primed seed gave a significantly higher percent early

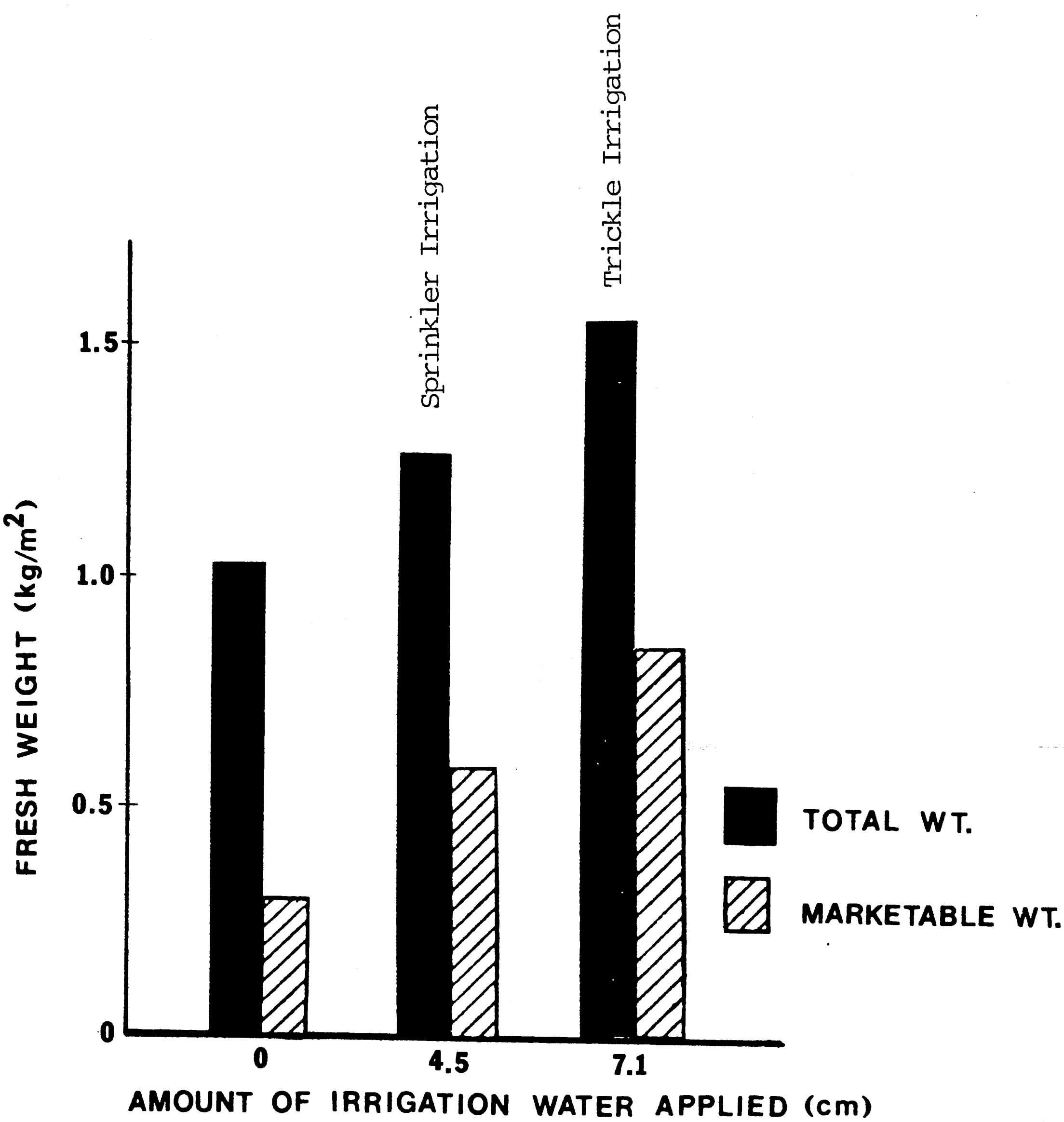

Figure 1. The Effect of Supplemental Irrigation, Applied by Two Different Methods, on the Yield of 'Waldmann's Green' Leaf Lettuce

TABLE III

THE EFFECT OF DIRECT SEEDING METHODS ON EARLY EMERGENCE AND STAND ESTABLISHMENT OF 'WALDMANN'S GREEN' LEAF LETTUCE

Seeding method	Percent early emergence[z]	Percent of desired postthinned stand obtained[y]
Primed	84.4a[x]	61.3b
Pelleted	81.3a	77.8a
Fluid drilled	74.7ab	78.2a
Raw seed	62.6b	74.2a

[z]Percent early emergence indicates the percent of the final prethinned stand which had emerged by the first emergence count, 10 days after sowing.

[y]The desired postthinned stand was one plant per 30.5 cm along the row.

[x]Mean separation in columns by Duncan's multiple range test, 5% level.

emergence than raw seed, but did not differ significantly from pelleted or fluid drilled seed. A significantly poorer final postthinned stand was obtained from the primed seed than from the other three seeding methods. However, analysis of variance showed no significant difference between the final prethinned stands of plots seeded with primed seed and those seeded with raw seed. Since both of these were sown with the same equipment and at the same rate, it seems reasonable to assume that any differences in the postthinned stands between the two methods were due to chance distribution of seedlings.

The average daily maximum soil temperature the first 10 days after sowing was 14.7°C, thus inhibition of seedling emergence was not encountered, as it was in Trials III and IV. Postthinned stands ranged from 61.3 percent to 78.2 percent of the desired stand, depending on the seeding method employed (Table III).

The effect of irrigation on emergence and final stand was not considered since irrigation was not applied until after final stands were obtained.

Trial VI - Fall 1984

Plots seeded September 7 produced an average of only 0.8 seedling per meter of row by September 25, despite the fact that sprinkler and trickle plots were irrigated immediately after planting and again on September 14. Emergence in all rows was too low to establish adequate stands, and the trial was discontinued. As in previous fall trials, warm soil temperature, favorable to pathogenic fungi, probably contributed to poor seedling emergence.

Variety/Stand Establishment Trials

Trial VII - Spring 1984

When the mean yields of the eight cultivars tested were compared by stand establishment treatment, much higher yields were obtained from the transplants than from either direct seeded method (Table IV), even though direct seeded crops were harvested after 61 days and transplants after 53 days. Contrast analysis showed the total fresh weight, mean fresh plant weight, and percent marketable plants to be significantly higher, at the 1% level, from transplants than from direct seeding. A stand establishment treatment by cultivar interaction was noted for marketable yield. This occurred because the marketable yields from transplants of two of the cultivars, 'Redhead' and 'Ruby,' were not significantly greater than those of raw seeded or fluid drilled plants of some of the other cultivars (Table V). Within each individual cultivar the marketable yield was significantly greater from transplants than from either of the direct seeded methods. Differences in yields between the two direct seeded treatments were nonsignificant.

Because yields from the direct seeded lettuce were negligible, a separate yield analysis was made from results of the transplanted crop only. Overall, the most productive cultivars were 'Waldmann's Green' and 'Deep Red,' with 'Grand Rapids T.B.R.,' 'Salad Bowl,' and 'Prizehead' being intermediate in productivity, while the lowest yields were obtained from 'Red Salad Bowl,' 'Redhead,' and 'Ruby' (Table VI). The cultivar 'Slobolt' was not included in the data analysis because of its questionable seed quality. Results from 'Green Ice' were also excluded because this cultivar did not exhibit true leaf lettuce

TABLE IV

THE EFFECT OF STAND ESTABLISHMENT METHODS ON THE YIELDS OF EIGHT LEAF LETTUCE CULTIVARS[z], SPRING 1984

Variable	Fresh weight[y] (kg/m^2) Total	Fresh weight[y] (kg/m^2) Marketable	Mean fresh weight per plant (g)	Percent marketable plants
Method of stand establishment				
Transplant	2.27	1.60	284	58.6
Raw seed	0.70	0.07	86	1.4
Fluid drill	0.64	0.04	84	3.2
Contrast				
Transplant vs seeded	**[x]	_[w]	**	**
Raw seed vs fluid drill	ns	_[w]	ns	ns

[z]Mean yields derived from yields of the following cultivars: 'Waldmann's Green,' 'Deep Red,' 'Salad Bowl,' 'Grand Rapids T.B.R.,' 'Prizehead,' 'Red Salad Bowl,' 'Ruby,' and 'Redhead.'

[y]All weights taken after trimming.

[x]ns,**: Contrasts nonsignificant or significant at 1% (**) level.

[w]Stand establishment treatment x cultivar interaction significant at 1% level.

TABLE V

THE EFFECT OF STAND ESTABLISHMENT METHOD ON THE FRESH MARKETABLE WEIGHT OF EIGHT LEAF LETTUCE CULTIVARS, SPRING 1984

Cultivar	Fresh marketable weight (kg/m^2)		
	Stand establishment method		
	Transplant	Raw seed	Fluid drill
Waldmann's Green	2.76^z	0.09	0.34
Deep Red	2.53	0.00	0.08
Grand Rapids T.B.R.	1.91	0.10	0.00
Salad Bowl	1.65	0.11	0.08
Prizehead	1.62	0.00	0.00
Red Salad Bowl	1.05	0.06	0.08
Redhead	0.65	0.00	0.00
Ruby	0.49	0.00	0.00

^{z}LSD, 0.05 (23 d.f.) = 0.48 within each cultivar and each stand establishment method.

TABLE VI

YIELDS FROM VARIETY TRIAL WITH EIGHT CULTIVARS OF LEAF LETTUCE ESTABLISHED FROM TRANSPLANTS, SPRING 1984

Cultivar	Fresh weight[z] (kg/m^2)		Mean fresh weight per plant (g)	Percent marketable plants
	Total	Marketable		
Waldmann's Green	2.96a[y]	2.76a	376a	88.7a
Deep Red	2.67ab	2.53a	327ab	89.3a
Grand Rapids T.B.R.	2.42b	1.91ab	306b	66.5ab
Salad Bowl	2.32b	1.65b	285b	60.7b
Prizehead	2.19bc	1.62b	268bc	64.3ab
Red Salad Bowl	1.85c	1.05bc	244c	49.4bc
Redhead	1.83c	0.65c	225c	28.6cd
Ruby	1.73c	0.49c	211c	21.4d

[z]All weights taken after trimming.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

characteristics, but was intermediate between leaf lettuce and head lettuce in appearance. Results from 'Green Ice' were also deleted from all subsequent trials.

No significant differences in percent early emergence or final postthinned stand were obtained between the two seeding treatments (raw seeding and fluid drilling). Some differences in the percent early emergence, although nonsignificant, were noted among the different cultivars, but this had no apparent direct correlation with the final postthinned stand (Table VII).

Trial VIII - Fall 1984

For the same apparent reasons as in Trial VI, lettuce seeded September 7 failed to establish a stand. By September 25 an average of only 0.9 seedling per meter of row had emerged. Examination of the pregerminated seeds used for fluid drilling showed that there was no problem with seed viability in either Trial VI or VII. A 50 seed sample from each cultivar, taken just before planting, showed at least 90 percent germination, as indicated by radicle emergence, in all cultivars except 'Ruby' which had 56 percent germination.

Results from the transplants showed 'Waldmann's Green,' 'Deep Red,' and 'Grand Rapids T.B.R.' to be the most productive cultivars in terms of total fresh weight and marketable weight (Table VIII). 'Black Seeded Simpson' produced a total weight comparable to that of 'Waldmann's Green' and 'Deep Red,' but the plants had bolted before harvest and were therefore not of marketable quality. Cultivars intermediate in total and marketable yields were 'Red Salad Bowl,' 'Prizehead,' and 'Redhead,' with the lowest yields obtained from 'Ruby'

TABLE VII

THE EFFECT OF DIRECT SEEDING METHODS ON EARLY EMERGENCE AND STAND ESTABLISHMENT OF EIGHT LEAF LETTUCE CULTIVARS, SPRING 1984

	Percent early emergence[z]		Percent of desired postthinned stand obtained[y]
	After 7 days	After 10 days	
Seeding method			
Raw seed	39.1ns[x]	63.0ns	81.9ns
Fluid drilled	36.4	55.4	82.6
Cultivar			
Salad Bowl	45.1ns[x]	70.8ns	81.9ns
Prizehead	42.5	59.2	88.9
Ruby	39.8	59.0	70.8
Deep Red	39.6	59.7	84.7
Waldmann's Green	37.5	59.2	79.2
Redhead	36.4	59.6	84.7
Red Salad Bowl	30.8	46.9	84.7
Grand Rapids T.B.R.	30.3	59.1	83.3

[z]Percent early emergence indicates the percent of the final prethinned stand which had emerged seven and 10 days after sowing.

[y]The desired postthinned stand was one plant per 30.5 cm along the row.

[x]Differences between the seeding method means and among cultivar means in each column nonsignificant at 5% level.

TABLE VIII

YIELDS FROM VARIETY TRIAL WITH NINE CULTIVARS OF LEAF LETTUCE ESTABLISHED FROM TRANSPLANTS, FALL 1984

Cultivar	Fresh weight[z] (kg/m^2) Total	Fresh weight[z] (kg/m^2) Marketable	Mean fresh weight per plant (g)	Percent marketable plants
Waldmann's Green	2.36a[y]	1.97a	280a	73.1a
Black Seeded Simpson	2.13ab	0.00d[x]	272a	0.0d
Deep Red	2.10abc	1.77a	267ab	73.9a
Grand Rapids T.B.R.	1.94abc	1.32ab	246ab	55.5ab
Red Salad Bowl	1.84bcd	0.92bc	217abc	38.1abc
Prizehead	1.79bcd	0.91bc	228abc	41.2abc
Redhead	1.62cd	0.64bcd	213abc	30.8bcd
Ruby	1.40de	0.00d[x]	165c	0.0d
Salad Bowl	1.11e	0.25cd	190bc	15.0cd

[z]All weights taken after trimming.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

[x]Plants had bolted by time of harvest and were therefore not of marketable quality.

and 'Salad Bowl.' Most plants of the cultivar 'Ruby' had also bolted by harvest and none of the remaining plants were of marketable size (≥250 g). Cultivar differences in mean fresh plant weight and percent marketable plants followed approximately the same trend as in the total and marketable yields (Table VIII). 'Salad Bowl' was aparently heat sensitive, as the survival rate was significantly lower than that of the other cultivars. This resulted in low yields for 'Salad Bowl.'

Bolting Trials

Trial IX - Spring 1984

Of the nine cultivars tested, 'Black Seeded Simpson' was the earliest to bolt, followed by 'Ruby' (Table IX). Only 'Black Seeded Simpson' had bolted by May 21, 45 days after transplanting. After 47 days 'Ruby' had also begun to bolt. After 53 days 100 percent of the plants in all cultivars had bolted, in response to increasing daylengths and high temperatures. By May 13 daily maximum and minimum temperatures had exceeded 31°C and 18°C, respectively. The high night temperatures may have promoted the formation of seedstalks (Raleigh, 1959).

A sample of 14 plants from each cultivar was used to estimate plant weight at optimum maturity. The average fresh plant weight was at least 250 g in all cultivars except 'Ruby,' which averaged 162 g. The percent of marketable plants was more than 70 percent in all cultivars except 'Redhead' and 'Ruby,' which had 50 percent and seven percent marketable plants, respectively.

TABLE IX

THE RELATIVE SUSCEPTIBILITY TO EARLY BOLTING OF NINE LEAF LETTUCE CULTIVARS GROWN IN SPRING 1984

Cultivar	Percent of plants bolted	
	45 days after planting	47 days after planting
Black Seeded Simpson	28.1a[z]	37.5a
Ruby	0.0b	25.0a
Waldmann's Green	0.0b	0.0b
Redhead	0.0b	0.0b
Red Salad Bowl	0.0b	0.0b
Grand Rapids T.B.R.	0.0b	0.0b
Salad Bowl	0.0b	0.0b
Deep Red	0.0b	0.0b
Prizehead	0.0b	0.0b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Trial X - Fall 1984

As in the spring, 'Black Seeded Simpson' and 'Ruby' bolted significantly earlier than the other cultivars tested (Table X). By November 6, 53 days after transplanting, 100 percent of 'Black Seeded Simpson' and 81 percent of 'Ruby' had bolted, along with 9.4 percent of 'Waldmann's Green.' After 61 days some bolting had occurred in all cultivars, but the percentages were significantly lower than those for 'Black Seeded Simpson' and 'Ruby.'

Though the daylengths in November were short, and night temperatures fairly cool, bolting may have resulted from earlier exposure of the plants to high temperatures (Thompson and Knott, 1933).

TABLE X

THE RELATIVE SUSCEPTIBILITY TO EARLY BOLTING OF NINE LEAF LETTUCE CULTIVARS GROWN IN FALL 1984

	Percent of plants bolted	
Cultivar	53 days after planting	61 days after planting
Black Seeded Simpson	100.0a[z]	100.0a[y]
Ruby	81.0b	81.0b
Waldmann's Green	9.4c	23.1c
Red Salad Bowl	0.0d	29.2c
Grand Rapids T.B.R.	0.0d	22.6c
Redhead	0.0d	19.4c
Deep Red	0.0d	18.9c
Salad Bowl	0.0d	12.6c
Prizehead	0.0d	5.8c

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

[y]Arcsin transformation of the percent means used to obtain separation by Duncan's mutiple range test, 5% level.

CHAPTER V

SUMMARY AND CONCLUSIONS

Field trials were conducted at the Oklahoma State University Research Station in Bixby, northeastern Oklahoma in order to evaluate certain cultural practices related to the commercial production of leaf lettuce (*Lactuca sativa*). The study included trials with irrigation and direct seeding methods, as well as variety trials which compared yields and the tendency towards premature bolting among selected cultivars.

In one trial, sprinkler, trickle, and subsurface irrigation were compared for their effect on yield and water use efficiency. With the total water applications differing by only 0.8 cm among the three irrigation methods, no significant differences in yields were observed. In another trial, irrigation significantly improved yields compared to nonirrigated control plots. Trickle irrigated plots received 2.6 cm more irrigation water than sprinkler irrigation plots, and produced significantly higher yields. Although trickle irrigation has been reported to improve water use efficiency in some crops, compared to sprinkler irrigation (Singh and Singh, 1978; Doss, Turner, and Evans, 1980; DeBoer, Peterson, and Evers, 1983), water use efficiency in both trials was greatest with sprinkler irrigation.

Direct seeding methods, using raw, pelleted, primed, and fluid drilled pregerminated seeds, were compared for their effect on earliness of seedling emergence, postthinned stand establishment, and subsequent crop yield. Direct seeding with raw, pelleted or fluid drilled pregerminated seeds provided a postthinned stand of at least 74 percent (of the desired stand) during the spring growing season. Stands obtained with seed primed in NaCl were somewhat less acceptable despite equal or better early emergence. Emergence from raw seed was slower than from pelleted, primed, or fluid drilled seed in one trial, but equal to that of fluid drilled seed in another trial.

When compared to lettuce grown in the spring from transplants, direct seeded lettuce (both raw and fluid drilled pregerminated) gave much lower yields even though the growing period for the direct seeded lettuce was eight days longer. Differences in yield between the two direct seeding methods were nonsignificant.

No acceptable stands were obtained from any of the four direct seeding methods in the fall, when soil temperatures exceeded 30°C.

In both spring and fall variety trials, 'Waldmann's Green was the highest yielding cultivar tested, in terms of marketable yield and mean fresh plant weight. 'Deep Red' and 'Grand Rapids T.B.R.' were comparable in yield to 'Waldmann's Green,' although 'Deep Red' was significantly lower yielding than 'Waldmann's Green' in one of three trials. Compared to these cultivars, 'Salad Bowl' produced intermediate yields in the spring trial, but grew very poorly with low yields in the fall. 'Black Seeded Simpson' produced plants comparable in weight to the highest yielding cultivars in the fall, but bolted early so it was not possible to compare marketable yields. In spring and fall, 'Prizehead' and 'Red Salad Bowl' were intermediate yielding cultivars, while the lowest yielding were 'Redhead' and 'Ruby.'

'Black Seeded Simpson' bolted earlier than any of the other cultivars tested, in both spring and fall. 'Ruby' bolted earlier than all cultivars tested except 'Black Seeded Simpson.' Other cultivars appeared to be equal in their tendencies toward early bolting.

Trickle irrigation has lower labor and operating costs and may be applied more frequently in lesser amounts than sprinkler irrigation (Davis, 1975). Under conditions requiring frequent, light irrigation applications the use of trickle irrigation, as compared to sprinkler irrigation, might increase yields of leaf lettuce. However, problems with clogging of the emitters, as experienced during the study, may limit the practical applicability of trickle irrigation of leaf lettuce.

Provided sprinkler irrigation can be applied as frequently as needed for optimum crop production of leaf lettuce, it appears to be at least as suitable as trickle irrigation, in terms of yield and water use efficiency. Subsurface irrigation, while allowing yields and water use efficiency comparable to those from sprinkler and trickle irrigation, required considerably more labor to install and was impossible to check for clogging. Therefore, it is not considered a promising method for irrigating lettuce.

Direct seeding with pelleted seed probably offers the best potential for establishing an acceptable stand with a minimum amount of seed, provided the precision metering components of the planting equipment can be properly matched to the size and shape of the pelleted seeds. Fluid drilling was the most troublesome and time consuming of the direct seeding methods, and at the moment does not allow accurate metering of the seeds.

Direct seeding lettuce where soil temperatures are high (>30°C) may result in inadequate stands, due to inhibition of seed germination or to damping-off of seedlings caused by thermophilic soil-inhabiting pathogens. Where the spring growing season is limited in length because of high temperatures late in the season, direct seeded lettuce would have to be planted considerably earlier than a transplanted crop in order to ensure optimal yields before plants began to bolt. Lettuce may also be subject to severe premature bolting if the seedlings are exposed to excessively high temperatures early in the growing season.

'Deep Red' appears to be the most promising of the red-leaved leaf lettuce cultivars tested, for commercial production in northeastern Oklahoma. Green-leaved cultivars showing the most potential are 'Waldmann's Green' and 'Grand Rapids T.B.R.' 'Black Seeded Simpson' would probably be a high yielding cultivar only if harvested early, since it tends to bolt quickly.

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