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**CRISPHEAD LETTUCE (*LACTUCA SATIVA* L.) CULTIVAR
EVALUATION AND RESPONSE OF TRANSPLANTS TO NITROGEN
NUTRITION**

M INST AGRAR (HORTICULTURE)

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DECLARATION

I, Livhuwani Lilly-Rose Madzivhandila, hereby declare that the dissertation, which I hereby submit for the degree M Inst Agrar (Horticulture) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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L. L. R. Madzivhandila

Dated this day of 2005.

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ABSTRACT

**CRISPHEAD LETTUCE (*LACTUCA SATIVA* L.) CULTIVAR
EVALUATION AND RESPONSE OF TRANSPLANTS TO NITROGEN NUTRITION**

by

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Degree: M Inst Agrar: Plant Production (Horticulture)

Experiments were conducted with lettuce at the field and in the glasshouse at the Hatfield Experimental Farm, University of Pretoria. The objectives of the study were to evaluate the performance of selected crisphead lettuce cultivars in relation to yield and quality performance and to investigate which level of nitrogen can produce high quality transplants.

In the lettuce cultivar trial, fifteen crisphead lettuce cultivars were grown, during March to May 2004. The experiment was laid out as a randomised complete block design with four replications. At harvest, the centre 20 plants were cut for yield determination and five uniform plants were then cut longitudinally for head quality characteristics. For each cultivar, compactness and uniformity were also evaluated and the number of days to maturity was recorded. Among the cultivars tested, the best yielding cultivars were Dual Purpose ($46.8 \text{ t}\cdot\text{ha}^{-1}$), Great Lakes ($45.8 \text{ t}\cdot\text{ha}^{-1}$), Mohawk ($44.3 \text{ t}\cdot\text{ha}^{-1}$) and Victory ($43.9 \text{ t}\cdot\text{ha}^{-1}$). Poor yielding cultivars were Taina ($30.5 \text{ t}\cdot\text{ha}^{-1}$), Cannon ($31.5 \text{ t}\cdot\text{ha}^{-1}$), Summer Time ($32.1 \text{ t}\cdot\text{ha}^{-1}$) and Classic ($33.2 \text{ t}\cdot\text{ha}^{-1}$). Del Rio was the best disease resistant cultivar, producing 100% marketable heads. All cultivars tested had good compactness and uniformity with the exception of Great Lakes 659. Early-maturing cultivars were ready 60 days after transplanting.

Seeds of the lettuce cultivar 'Aviram' were sown, in the nitrogen nutrition of lettuce transplant's trial. Two days after seeding, the seedlings were fertigated every second day by floating the trays in the plastic-lined tubs containing nutrient solution at 0, 30, 60,90 and 120 mg·L⁻¹ N until field capacity was reached. Transplants produced with 0 N grew poorly, regardless of the sampling date. Nitrogen at 120 mg·L⁻¹ improved the response of shoot growth, plant height and leaf area, but adversely affected root growth. In general, relative growth rate was improved while net assimilation rate was reduced as N level increased.

Root: shoot ratio decreased with applied N. The largest values of root: shoot ratio were obtained with 0 N. Both specific leaf area and leaf area ratio increased with applied N. Leaf mass ratio improved, while root mass ratio was reduced as N levels increased. At 35 days after sowing, leaf tissue N increased from 0.43 to 4.15 mg·kg⁻¹ with N applied. Only 25% of the plants produced without N could be pulled from the seedling trays, whereas 90% could be pulled when 90 mg·L⁻¹ N was added. This work suggested that at least 90 mg·L⁻¹ N, supplied via floatation irrigation was required to produce a transplant with sufficient roots for ease of pulling. Applying 90 mg·L⁻¹ N, resulted in improved root and shoot growth, resulting in high quality transplants.

Key words: Lettuce, cultivars, transplants, nitrogen.

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INTRODUCTION

Lettuce (*Lactuca sativa* L.) as a vegetable was recorded in Persia (Iran) about 500 B.C. and was used by the Romans during the early Christian era. It was known in China by the beginning of the 5th century (Soundy & Smith, 1992). Lettuce is a hardy annual, and botanically it is called *Lactuca sativa*. It is usually regarded as a derivative of the wild *L. scariola*, which is a widely distributed weed in Europe. Lettuce is a member of the largest family of plants, the Compositae, and belongs to the sub-division Linguliflorae (Large, 1972).

There are different types of lettuce: stem (*L. sativa* var *asparagina*) or asparagus lettuce, which can be used like celery (Splittstoesser, 1990). This relatively uncommon plant is grown for its thick, succulent stem. Another kind of stem lettuce includes cos or Romaine (*L. sativa* var *longifolia*) lettuce which have a more upright growth habit with a long head, if formed, and long spatulate leaves. If the heads form, they are self-closing with leaves curling inwards at the tips. Leaves appear course but are tender and sweet and damage easily (Hemy, 1984). The outer leaves are smooth and green; the inner leaves whitish green (Splittstoesser, 1990). Leaf lettuce (*L. sativa* var *crispa*) is also called cutting lettuce. Plants do not form a head and leaves may be serrated, deeply lobed, or crinkled. Leaf color varies from light green to red. The leaves of this variety can be picked progressively in the same way as spinach. Butterhead (*L. sativa* var *capitata*) is a head type in which the leaves are wrapped tightly over the short stem to form a round head close to the ground. Crisphead (*L. sativa* var *capitata*) or iceberg lettuce is the most popular in southern Africa. Leaves are thin and crisp and frequently have curled and serrated edges. Heads are hard and durable (Splittstoesser, 1990).

Lettuce thrives best in a relatively cool growing season with monthly mean temperatures of 12.8 to 15.6 °C. In areas having a mild winter climate and cool summers, lettuce is grown during the large part of the year. High temperatures are conducive to early seedstalk development with inferior quality (Soundy *et al.* 1992). Lettuce performs best in light, fertile and slightly acid soils and requires pH of 5.8 – 7.0 (Valenzuela, Kratky & Cho, 2003).

Lettuce is the most popular of the salad crops and is of great commercial importance. Its commercial value is only exceeded by potatoes and tomatoes in South Africa; where it is found in the market throughout the year. Lettuce occupies the largest area of the salad crops worldwide. It is a pleasure food with low nutrient density and serves as a source of bulk for diet conscious consumers (Salunke & Kadam, 1998).

More and more producers in South Africa are growing exotic vegetables, which are poorly adapted to their conditions. There is a great need therefore to grow cultivars that are eminently suitable for South African conditions. This has made cultivar trials and continuous testing essential.

Lettuce is a short cycled crop harvested between 61-78 days, especially during warm growing periods. The crop requires sufficient amount of N, P and K, absorbing 70 percent of the applied nutrients and accumulating most of its fresh weight three weeks preceding harvest (Karchi, Cantliffe and Dagan, 1992). Vegetable transplants grown in plug cells require careful management of fertilizers because of limited cell volume and high seedling densities. Concentrations of essential plant nutrients in the media are frequently insufficient to sustain plant growth given frequent irrigation (Soundy, Cantliffe, Hochmuth and Stoffella, 2001). Production of vigorous seedlings is a prerequisite for successful vegetable production, especially in lettuce, where the period of containerised growth comprises up to 30% of the entire crop cycle (Karchi *et al.*, 1992). Improved nutrient regimes would contribute to efficient development of high quality transplants (Soundy *et al.*, 2001).

Pretransplanting conditioning of seedlings may affect transplant stand establishment. Transplant nutritional conditions, particularly nitrogen availability, may play an important role in transplant quality and early yield (Nicola and Basoccu, 2000).

The selection of a nutritional regime to grow a specific vegetable transplant crop depends on the desires of the transplant grower and the farmer who buys the transplants. The transplant grower needs to produce a plant that is visually appealing and of acceptable quality to his customer. The farmer on the other hand, uses transplants because he usually wants earlier production and greater total yield (Dufault, 1998).

The purpose of this study was to evaluate the performance of different crisphead cultivars in relation to yield and quality performance and to investigate which level of nitrogen could produce high quality transplants

1 LITERATURE REVIEW

1.1 PRODUCTION OF VEGETABLE TRANSPLANTS

1.1.1 Growing vegetable transplants

Some of the most frequently grown and productive vegetables are commonly set into the field as transplants. These include tomatoes, peppers, eggplant, head lettuce, cabbage, cauliflower, broccoli and Brussels sprouts. Other plants that are sometimes set as transplants include watermelon, summer squash, okra and cucumbers (Kartz, 2003).

There are several advantages to using transplants rather than direct seeding. Earlier production from plants that are partially grown can result in higher prices for early vegetables and establish market contacts sooner. Uniformity and consistency of the crop can also result since direct-seeded crops are subject to heavy rains, wind and fluctuating soil temperatures (Marr, 1994; Kartz, 2003; Kerr, 2004).

Growth of transplants can be controlled more easily through fertility and water management. Transplants often result in better stands and earlier harvests; factors which can increase profits to offset additional production costs associated with transplanting. They also help save labour, with less need for hand weeding and thinning. Yield losses from poor germination are eliminated (Brault, Stewart & Jenni, 2002; Boyhan & Granberry, 2003).

Vegetable crops differ in their ability to be transplanted. The ability of the plant to survive, develop a new root system rapidly and recover from the transplanting process all influence transplanting. It is possible to group vegetable crops into several categories.

Easy to transplant crops are efficient in water absorption and rapid formation of new roots (beets, broccoli, cabbage, lettuce and tomatoes). Moderately easy to transplant crops do not absorb water as efficiently when young, but new roots form quickly (cauliflower, eggplant, onion and pepper). Difficult to transplant crops resume

growth slowly after the root system is injured. They require special care and handling (cucumber, melons and squash) (Marr, 1994).

1.1.2 Seed

High quality transplants can be produced only from high quality, living, and disease free seed. Seed packets should state the year the seed is intended for planting. If the seed is not intended for the current year, it may not germinate well, and seedling vigour may be reduced. For best germination, new seeds should be purchased every year (Johnson, 2003; Sams, 2003).

The seed must be stored in a cool, dry location to keep it alive and healthy as long as possible. Partially emptied seed packets may be resealed with tape, placed in a glass or plastic container, closed with a tight fitting lid and refrigerated. Some refrigerated seed will keep for several years. The stored seeds can be tested before planting it, by rolling a few seeds in a paper towel, moistening the towel and placing it in a container with a tight fitting lid. The container must be placed at room temperature for a week or ten days, and then the percentage of germinated seeds must be determined. The paper towel must remain wet the entire time (Sams, 2003).

To determine the actual germination percentage, Sams (2003) reported that the number of seeds that sprouted must be divided by the total number of seeds tested and multiplied by 100. For example, if 20 seeds were tested and 15 sprouted, then the germination percentage is 15 divided by 20 times 100 or 75 percent.

Commercial seed is grown to show trueness to type and to reduce the chances that it will contain diseases. The parent plants are inspected frequently for off-types or diseases. Insects are carefully controlled. Commercial seed is harvested, processed, packed and stored to ensure good germination (Johnson, 2003). Many vegetable seed companies treat their seeds with fungicide to prevent the seed from rotting in cold, wet soils and to reduce potential insect or disease losses. Seed from hybrid plants should never be saved, as it will not produce uniform plants that are true-to-type (Sams, 2003).

1.1.3 Growing media

Growing media must support plants, provide nutrients and allow infiltration of water. The media should be sterile, well drained, fine textured and free of insects, fungi, bacteria and weed seeds. The most commonly used media are pre-formulated mixes. Such mixes are recommended because of their adequate drainage, moisture holding capacity and nutrient retention capacity. In addition, they are generally free of insects, disease pathogens and weed seed (Rutledge, 1994).

1.1.3.1 Pre-formulated mixes

Ready-made mixes are available through garden, farm and horticultural supply stores. They contain the necessary ingredients to provide good aeration and moisture-supplying capacity. These mixes do not require pasteurisation prior to seeding, but sanitation, good ventilation and spray programs during plant growth are necessary to reduce the possibility of diseases such as damping-off (Rutledge, 1994).

Commercially prepared, lightweight mixes are convenient and easy to handle. However, care should be exercised when adding fertilizers to pre-formulated mixes to avoid over stimulation of plants, since some of them already contain the necessary nutrients for plant growth. The finer textured mixes available are good for seeding purposes, while medium textured media are preferred for growing plants (Rutledge, 1994).

The following on-site mixes can be used, but they are used less than pre-formulated mixes because of the labour and time required to prepare them:

1.1.3.2 Soil mix

A good soil mix consists of one part of shredded sterilised soil, one part peatmoss, vermiculite or perlite. It is generally better to use soil mixtures low in fertility and to add water-soluble fertilisers, if needed, while the plants are growing. However, mixes that use soil from any source are declining due to the availability, sterilization,

improved seed emergence and overall convenience of pre-formulated mixes (Marr, 1994).

1.1.4 Containers

Having the proper container helps get seedlings off to a good start and may save work in later stages of plant development. There are many containers suitable for sowing seeds (Bass, 1999).

1.1.4.1 Wooden flats, plastic trays and plastic pots

Plants that are easy to transplant may be seeded densely into flats, trays or pots. Later, the seedlings can be transplanted into individual pots or into wider spacings in flats. To avoid introducing damping-off organisms, previously used containers should be cleaned before re-using. The containers should be washed thoroughly in soapy water to remove all dried soil and debris. A disinfectant solution of one part chlorine bleach to ten parts water can be used as a rinse. The containers must be dried before the growing medium is added. Flats also can be used as master containers to hold individual plant containers, or seedlings can be transplanted into flats at recommended plant spacings (Bass, 1999).

1.1.4.2 Peat pots

These popular pots are made from peat and may be purchased individually or in strips or blocks. This type of container is porous, which provide excellent drainage. After filling the pots with potting mix, seeds can be sown into them. Peat pots generally last two to two and half months without crumbling or deterioration, yet plant roots penetrate the pot walls. For best results, peat pots should be placed tightly together in the flat to prevent rapid drying of containers and soil (Johnson, 2003).

1.1.4.3 Compressed peat pellets

When placed in water, these disks swell to form a cylindrical container filled with peat moss. Seeds are usually sown directly into the moistened pellets. It is also possible

to transplant seedlings into them. Pellets should be placed tightly together in trays or flats so that they are easily watered, held upright and less likely to dry out (Bass, 1999).

1.1.5 Seeding

Vegetables should be seeded so that they will be ready to be transplanted at the recommended planting dates. Most vegetables may be seeded with one or two seeds in a small cell pack or in rows in a seed flat. If they are seeded in flats, they will need to be transplanted into individual containers about five to ten days after they emerge, depending on the crop (Sams, 2003).

Once the seeds have germinated, they should be given sufficient sunlight to ensure the development of healthy stock plants. If bright sunlight is not available, an alternative is to use fluorescent lights. A fixture containing two 40-watt cool white fluorescent tubes spaced eight to ten centimetres apart is sufficient. The seedlings should be placed 15 to 20 cm from the tubes, and the light must be left on for 14 to 16 hours each day. The light must be raised to prevent leaf burn as the plants grow and the growing area should be warm. Generally, temperatures should be between 15.5 to 18 °C at night and 21 to 24 °C during the day. However, different vegetable transplants grow better at different temperatures (Bass, 1999).

1.1.6 Irrigation

Proper irrigation is extremely critical to transplant production. Seed will not germinate without moisture and seedlings will die quickly without moisture. Hotbeds, cold frames and seeding flats can dry out very quickly when exposed to direct sunlight. Vigorous applications of water can also destroy seedlings. The transplant must be irrigated frequently enough to keep the media slightly moist until the time to harden the plants. Over irrigation should be avoided as this causes root rot or damping-off (Schmidt, 2004).

If necessary, plants should be allowed to wilt slightly before irrigation to avoid the production of excessively tall, tender plants that do not recover rapidly when exposed

to adverse weather conditions. Slight wilting contributes to the production of hardened plants that respond well after transplanting to the field (Rutledge, 1994).

There are different irrigation systems that can be used during vegetable transplant production.

1.1.6.1 Overhead irrigation

This is the most commonly used irrigation system for production of containerised vegetable transplants. There are several ways to irrigate from overhead. Most containerised transplants are irrigated with automated, mobile systems with nozzled booms suspended over the flats. The boom travels the length of the house during an irrigation cycle. Properly maintained automated systems save labour and they apply pesticides and fertilizers uniformly; for transplant production on a small scale, a stationery system with mist nozzles can be used. Stationery systems are fairly inexpensive and can be constructed relatively easily. The nozzles must be precisely spaced to maximize uniform distribution of water, fertilizer and pesticides. This system does not assure uniform water flow through the medium, therefore, it can induce drought stress to the roots, change the root morphology, reduce root structure and function leading to reduction of cell growth and rates of cell division (Boyhan & Granberry, 2003).

1.1.4.3 Sub-irrigation systems

Ebb-and flow irrigation

This system is also known as floatation irrigation. It uses recycled stored or collected water, saving water and reducing fertilizer and pesticide use compared to overhead irrigation systems. Trays are suspended on metal wires 0.20 m above concrete floors, and every two to three days the irrigation water is raised to the level of the container, maintained for 15 to 45 minutes and then decreased to its original level or returned to the main reservoir until the next irrigation (Leskovar, 1998).

The floatation system was originally designed to grow tobacco (*Nicotiana tabacum* L.) plants to increase field survival and reduce transplant shock but now this system is being used to grow a large number of commercial vegetables (Rideout & Ovestreet, 2003; Rideout, 2004).

In this system, water moves by capillary action generally until cells are saturated. Previous studies found that ebb-and flow systems improved uniformity and quality of bell pepper, jalapeno pepper (*Capsicum annum* L.) and tomato (*Lycopersicon asculentum* Mill.) if grown with minimal nutrient and drought stress (Leskovar & Cantliffe, 1993; Leskovar & Boaks, 1995). However, in Europe there is concern that viruses including tomato spotted wilt virus, tomato mosaic virus and lettuce big vein virus are released from roots of diseased plants and spread by recirculating nutrient solution of the ebb-and flow irrigation system with the potential to contaminate the irrigation water and to infect healthy plants (Buttner, Marquardt & Fuhrling, 1995). Similarly, several plant pathogenic fungi such as *Pythium* sp. and *Phytophthora* sp. can cause persistent problems with recycled irrigation water (Pottorff & Panter, 1997).

There are several advantages to growing vegetable transplants using the floatation system. The application of the mineral nutrients can be easily monitored and precisely controlled using low cost, ion specific meters (Frantz, Welbaum, Shen & Morse, 1998). Since all water is applied directly to the roots and the foliage is not wetted, the likelihood of foliar diseases is reduced, labour costs for watering plants can be eliminated, and plants grow rapidly because roots are regularly in nutrient solution (Frantz *et al.*, 1998). However, there are several disadvantages to the floatation system as well, plants may be too succulent and overly susceptible to transplant shock. Little is known about the optimal nutrient concentration required to grow transplant of many horticultural crops. Diseases may spread rapidly through the nutrient solution and the polystyrene trays used for floatation system are not biodegradable, and disposing of used trays is a problem (Frantz *et al.*, 1998).

1.1.7 Fertilization

Vegetable seedlings will need some fertilization for best development. However, young tender seedlings are easily damaged by too much fertilizer. Most greenhouse crops are grown in some type of soilless medium, which does not contribute a significant amount of nutrients. Instead, these kinds of media mainly function as substrates that can hold water and nutrients, thus making them available to the roots (Kang & Van Iersel, 2004).

An effective fertilization program has to take into account both absolute amounts of nutrients supplied, as well as the availability of these nutrients to the plants. Availability of micronutrients in particular is depended on the pH of the growing medium. Thus, fertiliser programs have to take into account both the concentrations of fertilizer to be applied, and its effect on the pH of the growing medium (Huang, Nelson, Bailey, Fonteno & Mingis, 2002; Kang & Van Iersel, 2004).

Nitrogen fertilizer must not be applied on a weekly basis because this may induce rapid growth, which also results in excessively tall, unproductive plants. This is a good way to cause tomato plants to set their first cluster too high above the soil surface. This reduces the total number of clusters that a plant can produce and may reduce yield by as much as eight to nine percent per plant (Van Iersel, 2004).

When plants slow down in growth and become pale yellow, plants are usually fertilized with soluble fertilizer, which has been dissolved in a stock solution. This stock solution is metered into the irrigation lines and mixed with water during application. The application of fertilizer and water through the irrigation system is called fertigation. If a charged media (contains fertilizer) is used, fertigation is usually delayed one or two weeks. Otherwise fertigation should commence when the first true leaves begin to develop. During fertigation, the nutrient solution should be applied until it runs out the bottom of the flats. This ensures that all plants are frequently fertilized. In addition, this helps to prevent salt injury by leaching residual fertilizer salts from the media (Boyhan & Granberry, 2003).

Improved nutrient regimes would contribute to efficient development of high quality transplants. Seedling nutrition research is readily available on many vegetable crops. Generally, higher N-P-K regimes were associated with more vigorous seedling growth. Changing N rates from 10 to 250 mg·L⁻¹ and P rates from 5 to 25 mg·L⁻¹ increased shoot and root growth of 27-day-old muskmelon seedlings; also increasing K rates from 10 to 250 mg·L⁻¹ increased muskmelon shoot growth (Melton & Dufault, 1991).

Asparagus seedling shoot and root mass increased as N was increased from 100 to 200 mg·L⁻¹ with P at 20 mg·L⁻¹. Also, 350 mg·L⁻¹ enhanced broccoli, lettuce, pepper and celery seedling growth, but root growth decreased, and increasing P from 5 to 125 mg·L⁻¹ increased shoot growth without significantly changing root growth. Potassium rates of 200 mg·L⁻¹ produced higher broccoli and pepper shoot dry mass than 50 or 300 mg·L⁻¹ K. During seedling production, it is necessary to supply adequate N, P, and K; however, nutrient needs differ among crops (Melton & Dufault, 1991).

When growing transplants it must be kept in mind that the biggest plant is not always the best. In fact, it can be the most undesirable. The fertilizer program must be effectively managed to grow stocky, sturdy and medium green transplants that transplant and grow well in the field. The market must be considered when fertilizing. Some markets such as the retail bedding plant trade may desire larger, darker green transplants. Production of plants of this type usually requires slightly higher fertility levels. To successfully grow quality transplants, the fertility program throughout production should be managed carefully (Boyhan & Granberry, 2003).

1.1.8 Hardening of transplants

Plants, which have been growing indoors, cannot be planted abruptly into the field without injury. To reduce injury due to adverse weather, especially in spring, the transplants should be hardened-off before setting them into the field. Hardening-off is a process whereby plant tissues are toughened to withstand the outside environment.

Hardening should begin two weeks before field planting. To harden, plants can be moved to cooler areas outside, or the temperature can be reduced in the present location. Moving plants to a coldframe is an excellent way to harden plants. Cold tolerance of tomato seedlings increased after exposure to low temperatures (Ciardi, Vavrina & Orzolek, 1993). When moved outdoors, the plants should be kept in the shade at first, but gradually moved into full sunlight by increasing the period of exposure each day (Rutledge, 1994).

The frequency of irrigation must be reduced to slow growth, slight wilting will toughen the plants. Cold-hardy plants such as cabbage will be damaged if exposed to freezing temperatures before they have been hardened. After hardening some plants can be exposed to light frosts without being injured. Almost all the cool season crops can be hardened but warm season, vining crops cannot be hardened by reducing the temperature. They cannot tolerate cool temperatures, and if exposed, they will usually be stunted. Conditioning treatments for them involves reducing water and fertilizer (Rutledge, 1994).

Hardened plants can be recognized by a slight purple tinge in the leaf veins on the lower side of the leaf. If the entire underside of the leaf is purple, the plant is not only hardened but also stunted. Stunting plants should be avoided as this leads to poor quality transplants (Sams, 2003).

1.1.9 Transplanting

Transplants should be short and stocky; as wide or wider than they are tall. They should be free of leaf spots, yellowing and dying leaves and insects. Extremely large transplants are more likely to suffer transplanting shock and to grow slowly, bolt or even die than transplants of the proper size and age (Sams, 2003).

Transplants should be set into the field on a cloudy day or late afternoon. This will allow them to begin recovering from the transplanting shock before exposure to the hot sun. Transplants should be carefully removed from their containers and they should be set at the depth they previously grew or slightly deeper. Fibrous containers should be wet when transplanted and should not be removed, but must be

set deep enough to cover the rim of the container with a centimetre of soil. This prevents wicking or drying out. A half litre of water applied in the transplanting hole will reduce the transplanting shock and increase the survival, yield and earliness of the plants (Sams, 2003).

The spacing and layout of the crop will depend on the size of heads required, tractors and equipment used, and environmental conditions. Lettuce is usually planted on flat ground or small, shallow ridges, and if the soil is not well drained, raised beds can be used. Spacing plants too far apart may result in large heads but insufficient tonnage. Too close may give very good yield but, if heads are smaller than what the market requires, selling then will be difficult. A population of about 60 000 a hectare is a good starting point (Kerr, 2004). Salunke & Kadam (1998) recommended that lettuce seedlings could be transplanted in flat beds at a spacing of 45 x 45 cm or 45 x 30 cm.

Most growers find the use of Speedling transplants practical and convenient. It is true that with direct seeding there are fewer problems with damping-off and other soil diseases, but the advantages of seedlings far outweigh the disadvantages (Kerr, 2004). Seedlings give multiple benefits. The crop is in the land for much shorter time, which increases efficiency, saves water and pesticides, and makes weed control easier (Katz, 2003; Kerr, 2004). Costs are cut especially when expensive seed is required. Seedlings often allow one to get in an extra crop. They also help save labour, with less need for hand weeding and thinning (Brault, Stewart & Jenni, 2002; Kerr, 2004).

Farmers may be tempted to follow the system adopted in California, where more than 60 000 ha are directly sown every year, but this is unlikely to be successful here in South Africa. Californian conditions are vastly different to ours, their lands are very level and they apply laser technology. Their almost hazard-free climate makes germination easy and the size of their units permits specialised mechanical equipment, which reduces the number of labourers (Kerr, 2004).

Transplanting should be done so as to minimize damage and shock to the transplants. There is a great difference between a carefully planted and poorly transplanted crop when it comes to uniformity, soil diseases and overall yield. To

preserve the roots it is best to irrigate the land sufficiently in advance so that the transplants are planted into slightly moist soil. The seedlings should be wet when transplanted. Growers should ensure that the roots are not bent when transplanting. When roots are bent, the condition is called J-rooting and it causes stunting and a greater chance of diseases (Kerr, 2004).

1.2 LETTUCE FIELD PRODUCTION

1.2.1 Origin and history of lettuce

All lettuce plants developed from the wild species *Lactuca serriola* L. found in clearings, woods, rocky places and waste places from Asia and North Africa to northern Europe. It is a winter annual, germinating in autumn, and forming a rosette of leaves, which become very conspicuous on roadsides when they begin to flower in late summer, the stem reaching 2 m in height. The leaves are often spiny and usually held in a vertical position; they are obovate and entire or deeply lobed (Phillips & Rix, 1993).

The small flowers of *L. serriola* are pale yellow, and the seeds greyish-green. *virola* L. is similar but has flat leaves which has blackish seeds. It has been used in the breeding of some varieties such as 'Vanguard'. Another wild species, *L.saligna*, is an altogether slenderer plant with narrow leaves (Phillips & Rix, 1993).

Some closely related species are found in the mountains of Turkey, Iran and South Caucasus, and other wild lettuces are native to woods and plains in North America, including *L. canadensis*, sometimes called wild opium. *L. indica* L. is a perennial, a native of China and grown there and in Indonesia for its lanceolate stem leaves which are usually cooked, but may be eaten as salad (Phillips & Rix, 1993).

Lettuce was grown by the Romans, but is thought to have been cultivated first by the ancient Egyptians in around 4 500 BC. Wall paintings in some Egyptians tombs are thought to represent a narrowly pointed form of cos lettuce, though there are suggestions that the plant was first cultivated for edible oil in its seeds rather than as salad (Phillips & Rix, 1993).

Lettuce as a food plant was probably introduced to Britain by the Romans, who favoured the plant after it was said to have cured the Emperor Augustus (Phillips & Rix, 1993). It is known to have been widely eaten for over 2 000 years (Large, 1972). It was known in China by the beginning of the 5th century (Splittstoesser, 1990).

The Greeks and Romans grew lettuce and Theophrastus mentions three varieties. Cos lettuce is thought to have been introduced from Greece, since the name is derived from the island of Cos, in the Greek Archipeligo (Large, 1972). Phillips & Rix (1993) reported that lettuce seeds were taken to America by the early settlers.

1.2.2 Botanical description

Lettuce (*L. sativa*) is an annual belonging to the family Compositae. According to Salunke & Kadam (1998), there are four distinct types of subspecies or botanical varieties: head var. *capitata*, cutting or leaf, var. *crispa*, cos or Romaine, var. *asparagina*. There are two classes of head lettuce known as crisphead and butterhead.

1.2.3 Environmental requirements

Lettuce is a cool-season crop and grows best at a relatively cool temperature of about 12 °C to 15 °C (Hartmann, Flocker & Kofranek, 1981). Heading is prevented by seed stalk formation when temperatures reach 21 °C to 26 °C; also the leaves develop a bitter taste, therefore cool nights are essential for quality lettuce production (Salunke & Kadam, 1998).

Adequate moisture and cool temperatures are necessary at the time of heading. Low moisture and high temperature may cause a disorder called tipburn in which the tip of the inner leaves in the head show necrosis (Yamaguchi, 1983).

Lettuce is adapted to a wide range of soil types and prefers a slightly acid pH (6 to 6.5), but will still perform well when the pH is up to about 7.6 (Ware, 1980; Kerr, 2004). It will respond well to organic matter but this should not be overdone, as too

much nitrogen in the latter half of the crop's life can be detrimental. The crop can grow so lush that it sacrifices head size for outer leaves, especially in hot weather. (Kerr, 2004). If high temperature is a problem, it should be remembered that heavier soils are often cooler than light sandy soils. Soils with high water-holding capacity and good drainage are better for the lettuce root system (Hartman *et al.*, 1981).

1.2.4 Fertilization and irrigation

Fertilizer application should be based on crop nutrient demands and stage of crop growth. Excessive fertilizer application beyond crop needs may result in soluble salt build up; lettuce has a moderately low salt tolerance. Soluble salt injury results in poor germination and reduced head size (Valenzuela *et al.*, 1994).

Lettuce responds well to kraal manure, if available; otherwise 600 kg of 2:3:4 per hectare can be used if there is no soil analysis available. The soil should be analysed to determine plant requirements, perhaps with the help of fertiliser representative (Nagata, Sacher & Coale, 1992; Kerr, 2004).

Almost all of the South African lettuce is sprinkler irrigated. Ideally, the soil should be moist where the roots are placed in the soil with a light irrigation to follow shortly. Frequent, light irrigations are required until the roots start to grow into the soil. Moisture is not easily transported from the soil into the growing medium due to the different texture, and it is possible for the soil to be fairly wet and the "plug" rather dry (Kerr, 2004).

Fluctuations in soil moisture, especially during the later stages of development, are detrimental to optimal growth and head formation. Too much water during this period along with high temperatures may result in loose, puffy heads in heading types of lettuce. Dry conditions during this period, on the other hand, may induce premature bolting (Valenzuela *et al.*, 1994).

Irrigation should be done early in the morning before the sun becomes hot, so that the plants will dry out rapidly and diseases will not spread (Valenzuela *et al.*, 1994). Head and leafy lettuce types require about 260 mm of water per week per hectare.

Windy and dry areas may require more water (Gallardo, Jackson, Schulbach, Snyder, Thompson & Wyland, 1996).

1.2.5 Pests and diseases

Pests and diseases are some of the hazards of vegetable production, but the degree to which they influence the success or otherwise is usually in the hands of the grower. In vegetable production pest and disease control is a balance between keeping them under control, as far as possible, and accepting the loss of a few plants, leaves, roots and malformations as inevitable. The long-term trend is towards natural and biological ways of countering pests and diseases. For example, there are cultivars of lettuce specifically bred for inbuilt disease and pest resistance (Hemy, 1984).

The most important pests of lettuce include cabbage looper (*Trichoplusia ni* Hubber) and corn earworm (*Heliothis virescenes* L). Aphids and flies are important as sucking insects and as transmitters of disease organisms. Aphid types include the following: green peach aphid (*Myzus persicae* Sulz), lettuce seed stem aphid (*Macrosiphum barri* Essig) and lettuce aphid (*Nasanovia ribis-negri* Mosley). The lettuce root aphid (*Pemphigus bursarius* L.) feeds on lettuce roots and can be quite destructive causing severe wilting, retarded growth and even death (Salunke & Kadam, 1998).

The most common diseases that affect lettuce include, damping-off and root rot (caused by *Rhizoctonia solani* Kuehn and *Phythium ultimum* Trow), downey mildew (caused by *Bremicia lactucae* Reg.), lettuce drop (caused by *Sclerotinia sclerotiorum*) and lettuce mosaic and big vein (caused by viruses) (Salunke & Kadam, 1998). Lettuce leaves are susceptible to infection by bacterial soft rot, big vein, downey mildew, gray mold rot and watery soft rot. Such infections occur in the form of discoloration or water-soaked spots, turning the leaves into a soft, slimy wet mass. Mold growth or sclerotial bodies are found on the surface of infected tissues (Pierce, 1987; and Salunke & Kadam, 1998).

1.2.6 Harvesting

The stage of harvest maturity depends on the variety of lettuce and the purpose for which it is grown. Head lettuce for market is allowed to grow to full size and to develop a solid head, but for home use it is often harvested before the head is well formed (Salunke & Kadam, 1998).

Harvesting should be done before heads bolt, crack and yellow or turn bitter. In most instances, head lettuce will be ready for harvesting in 70 to 80 days after transplanting. Only those heads that are firm should be cut (Riofrio, 2004; Sanders, 2004).

Most leaf types are ready in 50 to 60 days after seeding and 30 to 45 days after transplanting. In harvesting, the heads or plants should be cut at the soil surface, leaving as many of the wrapper leaves uninjured as possible. To minimize wrapper leaf damage during harvesting, a crop should not be cut when the heads are wet. The soiled and spoiled leaves on the base of the head should be removed before picking (University of Hawaii at Manoa, 2004).

2 LETTUCE CULTIVAR TRIAL

2.1 INTRODUCTION

Crisphead lettuce (*Lactuca sativa* L.) is the most popular among the salad crops as well as the most economically produced crop in South Africa (Qi, 2000; Zerkoune & County, 2000). Lettuce is rich in vitamins and minerals; its consumption is ever increasing, especially in urban areas. It grows well in a relatively cool season with a monthly average temperature of 12 to 15 °C. Lettuce is sensitive to daylength and high temperatures. High temperatures promote seed stems, cause bitter taste in the leaves and accelerate the development of tipburn and rot. Lettuce performs best when grown on a rich, friable soil with high organic matter and adequate nutrient levels (Qi, 2000).

Variety selection is an important management decision, potentially impacting the grower's profitability. Sources providing information on variety performance include literature and other information from private seed companies, informal discussions among growers and university-conducted trials. All of the above sources have unique strengths, and all should be considered when selecting varieties (Dofing, Walworth & Carling, 1996).

Important traits determining the suitability of lettuce varieties include general appearance, yield, head size, days to maturity and disease resistance. Head size is important because growers are required to pack a fixed number of heads per carton when harvesting, and also because head size influences consumer preference in the supermarket (Dofing *et al.*, 1996).

The ultimate goal of variety trials is not describing past performance, but rather predicting superior varieties for future years. The ranking of varieties, based on their average performance in head-to-head competition overtime provides powerful and objective information that should be considered when selecting varieties (Dofing *et al.*, 1996).

The objective of this investigation was to evaluate the performance of selected crisphead lettuce cultivars in relation to yield and quality performance.

2.2 MATERIALS AND METHODS

A field trial was conducted at the University of Pretoria's Experimental Farm (Lat. 25° 45'S, Long. 28° 16'E, Alt 1372 m). The region is a summer rainfall area with an average rainfall of about 650 mm per annum (October – March). The highest average monthly temperature is 30 °C (January), whilst the lowest monthly temperature is 1.5 °C (July). The soil type is a sandy loam. Climatic data for the period of the trial is presented in Table 2.1.

Table 2.1 Monthly weather data during the time of the cultivar trial (March to May 2004) in Pretoria

Month	Temperature (°C)		Rainfall (mm)
	Min	Max	
March	16.9	26.2	7.9
April	13.6	24.9	10.3
May	8.3	23.7	6.3

Fifteen crisphead lettuce cultivars (Table 2.2) were grown during the 2004 autumn season. Seeds were sown on 04 February 2004. The seeds were sown into 200-cavity polystyrene trays containing Hygromix media at a rate of three seeds per cavity and vermiculite was used to cover the trays after seeding. The seedlings were thinned to one plant per cavity one week after emergence.

Table 2.2 An alphabetical list of cultivars included in the trial and their suppliers

Crisphead Cultivars	Company
1. Cannon	Asgrow
2. Classic	Asgrow
3. Del Rio	Hygrotech
4. Dual Purpose	Mayford
5. Empire 2000	Hygrotech
6. Great Lakes	Mayford
7. Great Lakes 659	Hygrotech
8. Grizzly	Hygrotech
9. Mohawk	Hygrotech
10. Summer Time	Hygrotech
11. Taina	Mayford
12. Tropical Emperor	Hygrotech
13. Victory	Hygrotech
14. Winter Supreme	Mayford
15. XP 5174	Asgrow

During the first week the seedlings were watered twice daily with pure water, in a greenhouse (without temperature control). From the second week until transplanting time, which was 28 days after sowing, the seedlings were fertigated twice a week with Wonder 3:2:1 (22) Supranure Plus at a rate of 10 ml in five litres of water per application (Table 2.3). Pure water was also supplied three times a week to prevent build-up of salts.

Table 2.3 Composition and chemical concentration of fertiliser (Wonder 3:2:1) used for transplant production

Composition	Concentration (g/ kg)
Nitrogen (N)	87.00
Phosphorus (P)	58.00
Potassium (K)	29.00
Iron (Fe)	1.68
Manganese (Mn)	0.86
Copper (Cu)	0.40
Zinc (Zn)	0.30
Boron (B)	0.44
Molybdenum (Mo)	0.01

Seedlings were transplanted after four weeks. The experimental area was 20 x 38.2 m in size. Fifteen cultivars were planted on 3 x 2.1 m plots, at a spacing of 30 x 50 cm. There were 42 plants per plot in 6 rows of 7 each. The experiment was laid out as a randomised complete block design with four replications (Fig. 2.1). Prior to planting, 3:2:1(25) and KCl (50% K) fertilisers were broadcast at a rate of 150 kg·ha⁻¹ N, 100 kg·ha⁻¹ P and 200 kg·ha⁻¹ K. Plots were irrigated with overhead sprinkler system. Weeding was done by hand, as there are no registered chemicals for use on lettuce.

Different cultivars were harvested as they matured, with the centre 20 plants in a plot harvested at the same time, for yield determination. For each cultivar the number of days from transplanting to harvest were recorded.

Compactness and uniformity were evaluated on all 20 heads from each plot using a 1-5 scale (Soundy & Smith's, 1992):

- 1 = very poor
- 2 = poor
- 3 = moderate
- 4 = good
- 5 = very good.

Because yield alone is not necessarily an indication of the superiority of one cultivar over another, an attempt was also made to evaluate the cultivars for quality characteristics. Thus, at harvest, five uniform heads from each plot were cut longitudinally for internal quality assessment. The core ratio was determined by calculating the ratio of stem to head height. A record of disease incidence was also made.

The data set was analysed using the general linear model (GLM) procedure of the Statistical Analysis Systems (SAS, 1999). The treatment means were compared using Duncan's multiple range test at $P \leq 0.05$ level of significance.



Fig. 2.1 Layout of the field experiment with fifteen crisphead cultivars

2.3 RESULTS AND DISCUSSION

The results indicated that highly significant differences ($P \leq 0.05$) existed among the cultivars tested within each variable measured (Table 2.4 and ANOVA Table A3 of the Appendix). In Table 2.4, it is clear that the separation of means was wide, but most of the cultivars did not differ significantly from one another. Therefore, the performance of different cultivars was divided into groups of high (H), intermediate (I) and low (L) performers.

Several important variables must be considered when choosing a lettuce cultivar. The cultivar should be high yielding and produce a high percentage of marketable heads. The plants should be uniform in the field during the time of harvest. The colour must be attractive. A good cultivar must be tolerant of diseases. When cut open a relatively short core must be observed (Soundy & Smith, 1992). No one cultivar exhibited all these attributes.

Among the cultivars tested, the best yielding were Dual Purpose ($46.83 \text{ t}\cdot\text{ha}^{-1}$), Great Lakes ($45.77 \text{ t}\cdot\text{ha}^{-1}$), Victory ($43.90 \text{ t}\cdot\text{ha}^{-1}$), Mohawk ($44.20 \text{ t}\cdot\text{ha}^{-1}$) and Del Rio ($42.17 \text{ t}\cdot\text{ha}^{-1}$). Poor yielding cultivars were Taina ($30.5 \text{ t}\cdot\text{ha}^{-1}$), Cannon ($31.5 \text{ t}\cdot\text{ha}^{-1}$), Summer Time ($32.1 \text{ t}\cdot\text{ha}^{-1}$) and Classic ($33.2 \text{ t}\cdot\text{ha}^{-1}$). The greater average yield was due to the greater average head mass for Dual Purpose (702.5 g), Great Lakes (686.5 g), Victory (685.5 g), Mohawk (664.0 g), Grizzly (632.3 g) and Del Rio (632.6 g). The poor yield was due to the high percentage of undersized heads for Taina (457.3 g), Classic (473.1 g), Summer Time (480.8 g) and Cannon (497.6 g). These cultivars can be considered unmarketable because of their smaller head size. However, they might be suitable for markets that sell individually wrapped lettuce.

These results are comparable to Soundy & Smith's (1992) results wherein the higher yielding cultivars were, Green Velvet ($42.7 \text{ t}\cdot\text{ha}^{-1}$), Black Velvet ($42.0 \text{ t}\cdot\text{ha}^{-1}$), AVX 2001 ($41.0 \text{ t}\cdot\text{ha}^{-1}$), Climax ($41.5 \text{ t}\cdot\text{ha}^{-1}$), Calona ($40.0 \text{ t}\cdot\text{ha}^{-1}$), AVX 2000 ($40.5 \text{ t}\cdot\text{ha}^{-1}$), and Westlake ($40.3 \text{ t}\cdot\text{ha}^{-1}$). While, low yielding cultivars were Cannon ($29.4 \text{ t}\cdot\text{ha}^{-1}$), Ithaca 989 ($29.4 \text{ t}\cdot\text{ha}^{-1}$), Ithaca Palette EZ ($30.5 \text{ t}\cdot\text{ha}^{-1}$), Inesor ($30.9 \text{ t}\cdot\text{ha}^{-1}$), Saladin Zodiac EZ ($31.1 \text{ t}\cdot\text{ha}^{-1}$) and Tires ($32.5 \text{ t}\cdot\text{ha}^{-1}$). They also observed that the greater

Table 2.4: Performance of 15 crisphead lettuce cultivars at the University of Pretoria's Hatfield Experimental Farm, March to May 2004

Cultivars	Mean yield (t·ha ⁻¹)	Mean head mass (g)	Percentage harvest	Head height (mm)	Head diameter (mm)	Compactness (0-5)	Stem height (mm)	Stem diameter (mm)	Core ratio	Uniformity (0-5)	Days to maturity
Dual purpose	46.83 H ^(a)	702.5 H ^(a)	92.50	149 I ^(cd)	152 H ^(a)	4.9	52 I ^(cd)	28 I ^(bcde)	0.34 I ^(cd)	4	66 I
Great lakes	45.77 H ^(ab)	686.5 H ^(ab)	88.75	134 L ^(ef)	130 I ^(ef)	4.3	46 H ^(de)	27 I ^(cdef)	0.33 I ^(cd)	4	60 H
Mohawk	44.27 H ^(abc)	664.0 H ^(abc)	93.75	139 L ^(ef)	146 H ^(abcd)	4.9	54 I ^(bcd)	31 H ^(a)	0.39 L ^(ab)	4	64 I
Victory	43.90 H ^(abc)	658.5 H ^(abc)	90.25	153 H ^(bc)	143 H ^(abcde)	4.6	59 L ^(abc)	29 H ^(abcd)	0.38 L ^(abc)	4	67 I
Del Rio	42.17 H ^(abcd)	632.6 H ^(abcd)	100	155 H ^(abc)	148 H ^(abc)	4.7	63 L ^(abc)	30 H ^(abc)	0.41 L ^(a)	4	66 I
Grizzly	42.15 H ^(abcd)	632.3 H ^(abcd)	95.00	158 H ^(ab)	148 H ^(abc)	4.6	61 L ^(abc)	31 H ^(a)	0.38 L ^(abc)	4	66 I
Winter supreme	39.79 H ^(abcde)	595.7 H ^(abcde)	97.50	167 H ^(a)	150 H ^(a)	3.6	62 L ^(ab)	31 H ^(a)	0.37 L ^(abc)	4	68 I
Tropical emperor	38.51 I ^(bcdef)	577.7 I ^(bcdef)	98.75	144 I ^(cde)	141 H ^(abcde)	4.3	50 I ^(d)	26 I ^(efg)	0.35 I ^(bcd)	4	67 I
Empire 2000	36.85 I ^(cdef)	552.9 I ^(cdef)	96.25	144 I ^(cde)	136 I ^(bcdef)	4.3	51 I ^(d)	29 H ^(abcd)	0.35 I ^(bcd)	4	67 I
Xp 5174	36.21 I ^(cdef)	543.1 I ^(cdef)	90.00	145 I ^(cde)	133 I ^(def)	4.7	47 H ^(de)	26 I ^(defg)	0.32 H ^(de)	4	67 I
Great lakes 659	33.42 I ^(def)	501.25 I ^(def)	90.00	151 H ^(bcd)	133 I ^(cdef)	2.7	52 I ^(cd)	28 I ^(bcde)	0.34 I ^(cd)	3	71 L
Classic	33.17 L ^(ef)	497.6 L ^(ef)	95.00	135 L ^(ef)	124 L ^(f)	4.3	40 H ^(ef)	25 L ^(fgh)	0.29 H ^(ef)	3	66 I
Summer Time	32.05 L ^(ef)	480.7 L ^(ef)	90.00	129 L ^(fg)	126 L ^(f)	4.6	41 H ^(e)	22 L ^(h)	0.32 H ^(def)	4	68 I
Cannon	31.34 L ^(ef)	473.1 L ^(ef)	91.25	122 L ^(g)	122 L ^(f)	4.5	35 H ^(f)	24 L ^(gh)	0.28 H ^(f)	4	60 H
Taina	30.49 L ^(f)	457.3 L ^(f)	92.50	131 L ^(f)	124 L ^(f)	4.1	42 H ^(e)	24 L ^(fgh)	0.31 H ^(def)	3	71 L

Means with the same letters within the columns were not significantly different at $P \leq 0.05$ (Duncan's multiple range test)

0-1= very poor; 2 = poor; 3 = moderate; 4 = good; 5 = very good

The performance of different cultivars was divided into three groups: high (H), intermediate (I) and low (L)

average yield was due to greater average head mass for AVX 2000 (908 g), AVX 2001 (907 g), Green Velvet (875 g), Black Velvet (875 g), Climax (879 g) and Westlake (772 g).

Dofing, Walworth & Carling (1996) found that cultivar Coolgreen had the highest percentage of marketable heads, due mainly to its lower percentage heads that were too small to market. Walworth, Dofing & Carling (1997) also observed the same results wherein, among the cultivars tested, Bayview, Desert Storm and Jupiter gave the highest percentage of marketable heads.

The highest head height was observed with Winter Supreme (167 mm), Grizzly (158 mm), Del Rio (155 mm) and Great Lakes 659 (151 mm). In contrast, the shortest head height was observed with Cannon (122 mm), Great Lakes (128 mm), Taina (131 mm), Summer Time (133 mm) and Classic (139 mm) (Table 2.4). The results also indicated the largest head diameter to be that of Dual Purpose (152 mm), Winter Supreme (150 mm), Grizzly (148 mm), Mohawk (148 mm), Victory (143 mm) and Tropical Emperor (140 mm). The narrowest head diameter was observed with Classic (124 mm), Cannon (122 mm), Taina (124 mm) and Summer Time (125 mm).

Taller and wider heads often indicate good marketable size of good quality. Shorter and narrower heads, on the other hand, usually indicate size of poor quality, which can be considered unmarketable. Similar differences were reported by Kleinhenz & Schult (2000) where the highest head length was observed with cultivar Outredgeous MTO (298 mm) and P1368-7278 (279 mm) while shorter heads were observed with Dark Lollo Rossa (127 mm) and LO 9355 (127 mm). They also observed that cultivars PSR 5025, P1404-1272-1 and Outredgeous MTO had the largest head width at 432 mm, 425 mm and 406 mm respectively. In contrast, Diamond Gem MTO had the narrowest head according to Kleinhenz & Schult's (2000) results.

Similarly, Soundy & Smith (1992) observed the highest head height with XP 5196 (275 mm), XP575 (223 mm), AVX 2000(173 mm), AVX 2001 (172 mm) and Green Velvet (171 mm). Shorter heads were observed with Cannon (134 mm), Ithaca 989 (138 mm) and Great Lakes 659-700 (138 mm). They also observed the largest heads diameter with XP 575 (272 mm), XP 5196 (175 mm), Inesor (160 mm) and

Frosty (153 mm). In contrast, they observed narrower heads with cultivar Inesor (131 mm), Ithaca Palette EZ (131 mm), Ithaca 989 (135 mm) and Cannon (135 mm).

Among the cultivars tested, the shortest stem height was observed with Cannon (34.80 mm), Classic (39.65 mm), Summer Time (40.60 mm), Taina (41.60 mm), Great Lakes (46.23 mm) and XP 5174 (47.25 mm). In contrast, the longest stem height was observed with Del Rio (63.35 mm), Winter Supreme (61.70 mm), Grizzly (61.20 mm) and Victory (59.35 mm). The results indicated the widest stem diameter with Winter Supreme (31.25 mm), Grizzly (31.05 mm), Mohawk (31.00 mm), Del Rio (29.65 mm), Empire 2000 (29.10 mm) and Victory (28.80 mm) (Table 2.4). The reason for shorter and narrower stems may be probably related to the season and to the cultivars that are relatively resistant to bolting. Such cultivars are good for hot temperatures and those that do better in cooler climates will bolt in summer for example. Longest stem height is undesirable because it indicates that plants will bolt.

These results are comparable to that of Soundy & Smith (1992) where the longest stem height was observed with Crispy (125 mm), AVX 2000 (111 mm), XP 575 (111 mm) and Inesor (99 mm). The results of the present study confirmed Soundy & Smith's (1992) results in which shortest stem height was observed with Cannon (38 mm), Classic (45 mm), Fame (46 mm), Ithaca (46 mm) and XP 5174 (46 mm). These cultivars will, therefore, do better during warmer seasons.

Among the cultivars tested, the shortest core ratio was observed with Cannon (0.283), Classic (0.293), Taina (0.315), Summer Time (0.315) and XP 5174 (0.324). The highest core ratio was observed with Del Rio (0.408), Mohawk (0.387), Victory (0.385), Grizzly (0.385) and Winter Supreme (0.369). The best cultivar should have a relatively short core or stem. Similarly, Soundy & Smith (1992) observed that cultivar Crispy, AVX 2000 and Black Velvet had the highest core ratio at 0.788, 0.659 and 0.643, respectively. While, XP 5196 and Cannon had the lowest core ratio at 0.268 and 0.239.

All cultivars tested had good compactness with the exception of Great Lakes 659. However, uniformity was very good among all the cultivars tested (Table 2.4). Early-

maturing cultivars were ready 60 days after transplanting. Brault & Stewart (2002) also observed earliness in head lettuce. Taina and Great Lakes 659 varieties had delayed maturity as compared to the rest of the other cultivars. Great Lakes 659 produced a higher percentage of loose heads with very large leaves that indicated off types. Thus, this cultivar might be better suited grown as baby lettuce. Taina produced higher percentage of undersized heads (Table 2.4). No explanation can be offered for the poor compactness. Dimsey & Murdoch (2001) also observed delayed maturity with cultivar Greenway while many heads did not close. Similarly, Zerkoune (2000) also observed that there was a delay in maturity for cultivar Kahuna, GX 166 and Deplomat compared to the rest of the other cultivars. Dofing *et al.* (1996) also obtained delay in head lettuce coupled with a higher percentage of undersized heads.

On average most cultivars took about 64 to 66 days to mature. For lettuce, harvesting must proceed within a certain narrow time interval for quality is an important factor (Soundy & Smith, 1992).

Among the cultivars tested, Del Rio was the best disease resistant cultivar, producing 100% of marketable heads (Table 2.4). This result is comparable to Soundy & Smith's (1992) results in which Wallop had a harvest percentage of about 100%. The high percentage harvest of head lettuce was also observed in a trial with cultivar Gemini that had the highest percentage in one clean harvest (Thompson, 1992). In the present study, all the tested cultivars had relatively high harvest percentages of 90% and above with the exception of Great Lakes which had a harvest percentage of 88% (Table 2.4). Although cultivar Great Lakes had a fairly high percentage of marketable heads, its disease resistance was, however, the poorest of any variety.

Dofing *et al.* (1996) and Hill (1999) obtained the same results with cultivar Coolgreen which had a fairly high percentage of marketable heads, but its tipburn resistance was the poorest of any variety. There was a low disease incidence during the later stages of growth development. The most prevalent disease was *Sclerotinia* rot. This is a serious disease, which causes the outer leaves to wilt (Fig. 2.2). To control the disease, plants have to be widely spaced and overhead irrigation must be avoided to keep the soil surface dry (Amodor & Wesloco, 1996).



Fig. 2.2 *Sclerotinia* rot on planted lettuce cultivars

2.4 CONCLUSIONS

The experimental results indicated that Dual Purpose, Great Lakes, Victory, Mohawk and Del Rio were suitable varieties under the University of Pretoria's Experimental Farm conditions, due to their high yield and good quality characteristics. Del Rio was also the best disease resistant cultivar.

The selected cultivars of head lettuce were judged on yield, quality and disease resistance. These judgements are based on the observations for one season only for each cultivar. Variety trials must be conducted over several years to determine average performance across a range of environmental conditions. Yield and quality may change from season to season due to variations in weather during their development in the field. Therefore, results from this trial should not be considered definitive, but rather should be interpreted in the context of expected on-farm performance. However, cultivars which were not recommended because they are

low yielding due to a small average head mass, but otherwise good, could actually be suitable for markets where each head is wrapped individually.

In future, soil and leaf analysis should be carried out at each time of planting and at two stages of growth in order to determine if there are any nutrition-related leaf disorders. It would also be advisable to conduct cultivar trials in different areas of Pretoria in order to make recommendations to a broader spectrum of farmers.

2.5 SUMMARY

Continuous cultivar testing is necessary under any conditions as new cultivars are being introduced every year. Fifteen crisphead lettuce cultivars were grown during March to May 2004 at the Hatfield Experimental Farm, University of Pretoria, with the aim of evaluating their performance in relation to yield and quality characteristics. The experiment was laid out as a randomised complete block design with four replications. At harvest, the centre 20 plants were cut for yield determination and five uniform plants were then cut longitudinally for head quality determination. For each cultivar, compactness and uniformity were evaluated and the number of days to maturity was recorded.

Among the cultivars tested, the best yielding were Dual Purpose ($46.8 \text{ t}\cdot\text{ha}^{-1}$), Great Lakes ($45.8 \text{ t}\cdot\text{ha}^{-1}$), Mohawk ($44.3 \text{ t}\cdot\text{ha}^{-1}$) and Victory ($43.9 \text{ t}\cdot\text{ha}^{-1}$). Poor yielding cultivars were Taina ($30.5 \text{ t}\cdot\text{ha}^{-1}$), Cannon ($31.5 \text{ t}\cdot\text{ha}^{-1}$), Summer Time ($32.1 \text{ t}\cdot\text{ha}^{-1}$) and Classic ($33.2 \text{ t}\cdot\text{ha}^{-1}$). Del Rio was the best disease resistant cultivar; producing 100% marketable heads. All the cultivars tested had good compactness and uniformity with the exception of Great Lakes 659. Early-maturing cultivars were ready 60 days after transplanting. Taina and Great Lakes 659 had delayed maturity as compared to other cultivars.

3 NITROGEN NUTRITION OF LETTUCE TRANSPLANTS

3.1 INTRODUCTION

Selection of a nutritional regime to grow a specific vegetable transplant crop depends on requirements of the transplant grower and the farmer who buys the transplants. The transplant grower needs to produce a plant that is visually appealing and of acceptable quality to his/her customer. The farmer, on the other hand, uses transplants because he/she usually wants earlier production and greater total yield (Dufault, 1998).

Vegetable transplants grown in plug cells require careful management of fertilizers because of the limited cell volume and high seedling densities. Concentrations of essential plant nutrients in the media are frequently insufficient to sustain plant growth given frequent irrigation (Soundy *et al.*, 2001). Production of vigorous seedlings is a prerequisite for successful vegetable production, especially in lettuce, where the period of containerised growth comprises up to 30% of the entire crop cycle (Karchi *et al.* 1992). Improved nutrient regimes would contribute to efficient development of high-quality transplants (Soundy *et al.*, 2001).

Seedling research is readily available on many vegetable crops. Generally, high N regimes were associated with more vigorous seedling growth. Increasing the N concentration from 10 to 250 mg· L⁻¹ increased celery (*Apium graveolens* L.) shoot and root growth. Increasing N from 25 to 225 mg· L⁻¹ increased watermelon (*Citrullus lanatus*) shoot and root growth (Dufault, 1998). Melton & Dufault (1991) reported that N at 400 mg· L⁻¹ increased tomato (*Lycopersicon esculentum* Mill.) seedling size. Asparagus (*Asparagas officinalis* L.) seedling shoot number, shoot, root and total dry mass increased as N was increased from 50 to 150 mg· L⁻¹ (Nicola & Basoccu, 2000).

Studies have shown that overhead irrigation of transplants does not assure uniform water flow through the medium and it can induce stress to the roots, change the root morphology, reduce root structure and function and contribute to pathogen attack. Growers using the overhead irrigation system have had problems producing lettuce

transplants with sufficient roots in a tray cell to allow their removal from the seedling trays (Soundy *et al.*, 2001). According to Leskovar (1998) sub-irrigation (floatation) allows 50 to 60% reduction of pesticide and 50% of fertiliser use. In the present investigation the N concentrations were supplied via floatation irrigation, required for production of easy-to-pull transplants, which would establish rapidly in the field.

The purpose of this study was to investigate which level of nitrogen could produce high quality transplants. When growing transplants, it should be known that the biggest plant is not always the best. In fact, it can be the most undesirable. Good quality transplants should have sufficient roots for ease of pulling.

3.2 MATERIALS AND METHODS

The experiment was carried out in a glasshouse at the Hatfield Experimental Farm (Lat. 25° 45' S, Long. 28° 16'E, Alt. 1372m) of the University of Pretoria. Two hundred-cavity trays were cut into four to produce four trays with 50 cavities. Seeds of the lettuce cultivar 'Aviram' were sown. A commercial media (Culterra seedling soil) with no added fertilizer was used as the growth medium. The planter trays were then covered with a layer of vermiculite, and overhead irrigated sufficiently to moisten the vermiculite. The experiment was arranged in a randomised complete block design with five nitrogen treatments, each replicated four times. The treatments consisted of 0, 30, 60,90 and 120 mg·L⁻¹ N. Phosphorus (P) and potassium (K) were supplied from 209.6 mg of potassium dihydrogen phosphate (KH₂PO₄) to provide 60 mg·L⁻¹ of K and 47.6 mg·L⁻¹ P. Both P and K were supplied at equivalent rates to all plants. Two days after seeding, the seedlings were fertigated every second day by floating the trays in the plastic-lined tubs (Fig. 3.1) until field capacity was reached.

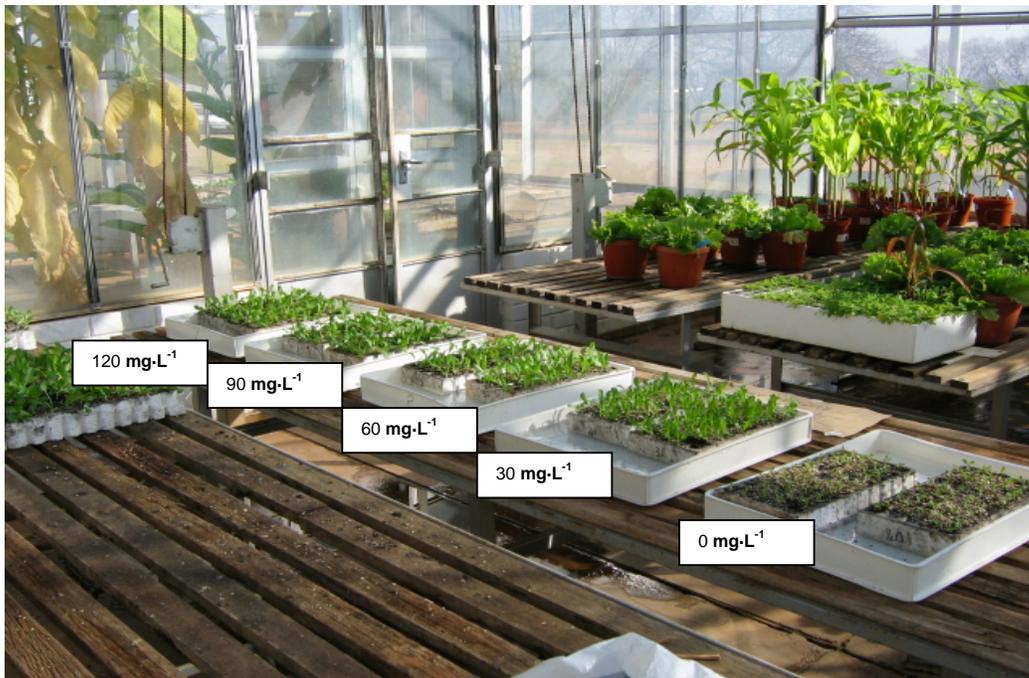


Fig 3.1 Plastic tubs used to fertigate lettuce transplants with various levels of N

Transplants were thinned to two per cell at the cotyledonary stage and to one transplant prior to the first sampling date. Five plants from each treatment were sampled at 21, 28 and 35 days after sowing (DAS). The sampled plants were removed from the trays and washed gently before growth measurements were taken. Measurements included shoot and root fresh mass, plant height, leaf count and leaf area (measured by LI 3100 leaf area meter; LI-COR, Lincoln, Neb.). Shoots and roots were separated and oven-dried at 65 °C for two days and dry mass determined.

Growth variables calculated included (Dubik, Krizek, Stimart & McIntosh, 1992 & Hunt, 1982) :

- Root: shoot ratio (RSR = dry root mass ÷ dry shoot mass)
- Relative growth rate (RGR = [Ln (final total dry mass) - Ln (initial total dry mass) ÷ (final time - initial time)])
- Net assimilation rate (NAR = [final total dry mass – initial total dry mass) ÷ (final time - initial time) × {(Ln (final leaf area) – Ln (initial leaf area)) ÷ (final leaf area - initial leaf area)])
- Specific leaf area (SLA = leaf area ÷ dry shoot mass)

- Leaf area ratio (LAR = leaf area ÷ total dry mass)
- Leaf mass ratio (LMR = dry shoot mass ÷ total dry mass)
- Root mass ratio (RMR = dry root weight ÷ total dry mass).

At the final sampling date (35 DAS), pulling success (%) was calculated from five plants sampled within each treatment that could be removed from the seedling trays without breakage. Dry shoot samples from the last sampling dates were ground for nitrogen analysis. Nitrogen was determined on a 300 series rapid flow analyser (ALPKEM Corp., Wilsonville, Ore.).

Data were subjected to analysis of variance using the Statistical Analysis System (SAS Institute, 1999). Treatment sums of squares were partitioned into linear and quadratic polynomial contrasts.

3.3 RESULTS AND DISCUSSION

Fresh and dry shoot mass increased linearly in response to applied N for plants sampled 21 and 28 days after sowing (DAS). Fresh and dry shoot mass increased quadratically in response to applied N for plants sampled 35 DAS (Figs 3.2 and 3.3). The highest increases in shoot mass in response to applied N occurred between 0 and 90 mg·L⁻¹, regardless of sampling date. Liptay, Nicholls & Sikkema (1992) observed similar results with tomato seedlings, where the seedling growth increased with increased N levels from 50 to 350 mg·L⁻¹. A similar response was also obtained again with tomato transplants, where seedling shoot growth increased with increasing N rates, from 20 to 150 mg·L⁻¹ Liptay, Nicholls & Sikkema (1992). Similarly, Karchi & Cantliffe (1992) observed that the increase in leaf mass of lettuce transplants was due to an increase in N from 58 to 292 mg·L⁻¹ in the nutrient solution.

The increase in shoot mass might be due to high levels of nitrate, because plants absorb nitrogen as either ammonium (NH₄) ions or as nitrate (NO₃) ions. When nitrate levels are high, plants can accumulate nitrates in certain tissues above what is needed at that stage of growth (Peduto, 1998).

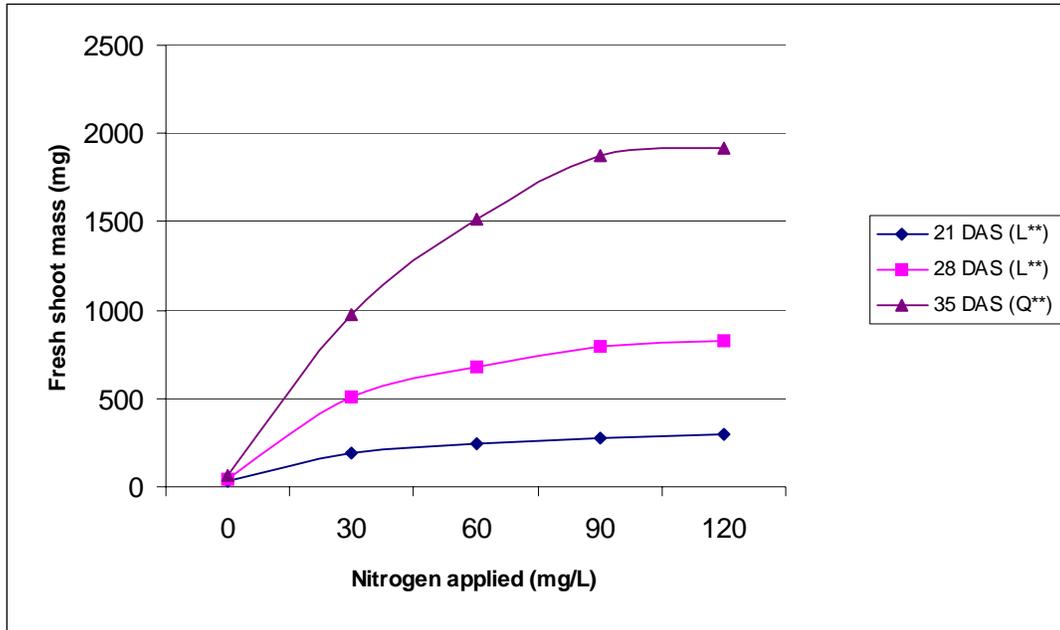


Fig. 3.2 Lettuce transplants fresh shoot mass response to N nutrition. Linear (L) or quadratic (Q) effects non-significant (NS) or significant at $P = 0.05$ (*) and 0.01 (**)

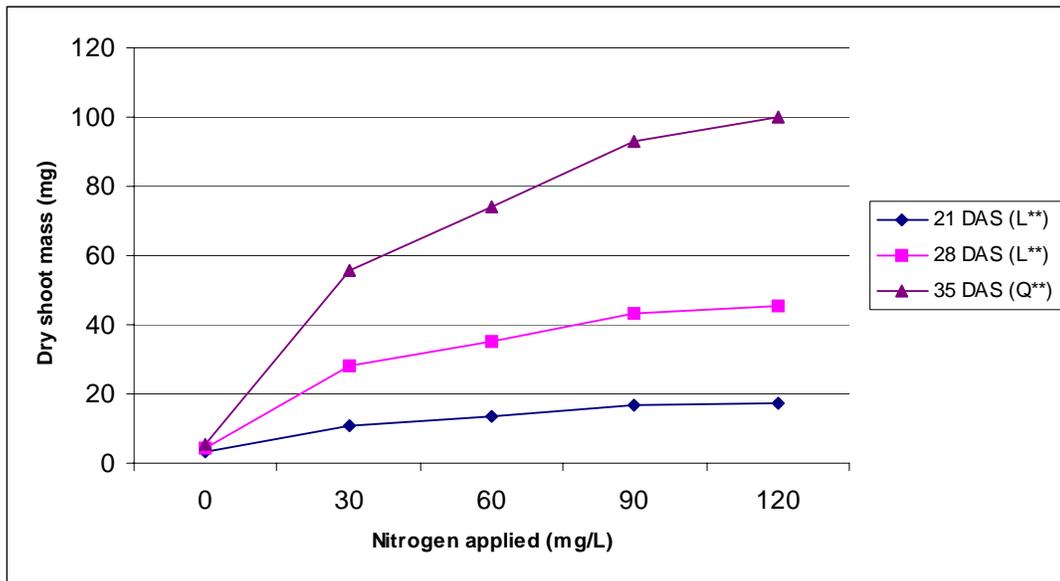


Fig. 3.3 Lettuce transplants dry shoot mass response to N nutrition. Linear (L) or quadratic (Q) effects non-significant (NS) or significant at $P = 0.05$ (*) and 0.01 (**)

For plants sampled 21 and 28 DAS, fresh and dry root mass increased quadratically as N rates increased from 0 to 90 mg·L⁻¹, and decreased at 120 mg·L⁻¹ N level (Figs 3.4 and 3.5). For plants sampled 35 DAS fresh and dry root mass increased quadratically with increasing N rate from 0 to 30 mg·L⁻¹, decreasing at 60 to 120 mg·L⁻¹ level of N (Figs 3.4 and 3.5). Highest increases in root mass in response to applied N occurred between 0 and 30 mg·L⁻¹, for 21 DAS. This indicated that high N levels reduced root growth. Similar results were found with lettuce, where transplants, grown with 60 mg·L⁻¹ had greater root mass than those grown with 100 mg·L⁻¹ N (Soundy *et al.*, 2001).

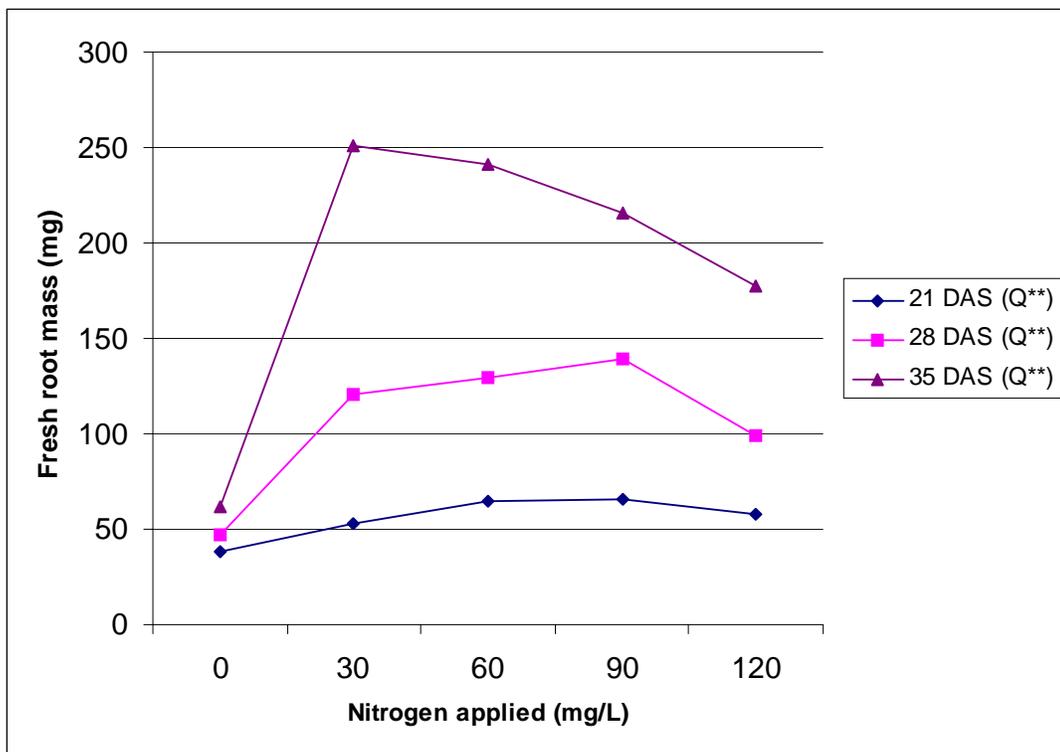


Fig. 3.4 Lettuce transplants fresh root mass response to N nutrition. Linear (L) or quadratic (Q) effects non-significant (NS) or significant at P = 0.05(*) and 0.01 (**)

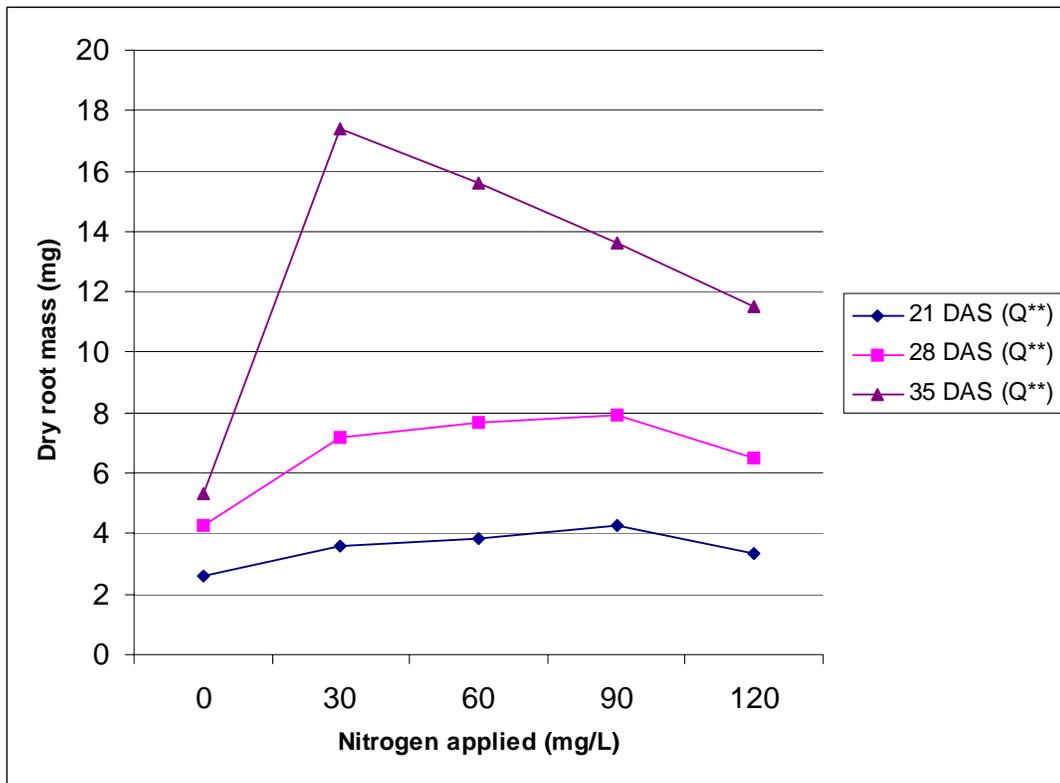


Fig. 3.5 Lettuce transplants dry root mass response to N nutrition. Linear (L) or quadratic (Q) effects non-significant (NS) or significant at $P = 0.05$ (*) and 0.01 (**)

These results also confirm Dufault's (1998) results in which nitrogen level as high as $400 \text{ mg}\cdot\text{L}^{-1}$ increased shoot growth but decreased root growth. Reduced root N content with increasing N might have been induced by loss of available N, a decrease in N uptake or reduced transport of assimilated or free N to roots.

Height control is an important production consideration for the transplant nursery and the grower. Large transplants are difficult to handle and may be seriously damaged during mechanical transplanting. Plant height increased linearly in response to applied N, regardless of sampling date (Table 3.1). Similar results were found with bell pepper seedlings, where the seedling height increased as nitrogen levels increased (Dufault & Schlutheis, 1994).

Table 3.1 Root and shoot characteristics of lettuce transplants as affected by N Nutrition, July/August 2004

N applied (mg·L ⁻¹)	Plant height (mm)	Leaf area (cm ²)	Root:shoot ratio	Pulling success (%)	Leaf tissue N (%)
<i>21 Days After Sowing</i>					
0	21.45	0.92	0.88		
30	54.05	6.29	0.33		
60	61.20	8.07	0.29		
90	63.95	9.32	0.25		
120	64.75	10.18	0.19		
Response	L**	L**	L**		
<i>28 Days After Sowing</i>					
0	22.50	1.00	0.94		
30	76.75	14.70	0.25		
60	87.95	19.68	0.22		
90	92.95	22.91	0.18		
120	96.10	25.53	0.14		
Response	L**	L**	L**		
<i>35 Days After Sowing</i>					
0	25.05	1.14	0.99	25	0.43
30	91.15	25.67	0.31	60	1.85
60	107.7	44.79	0.21	65	3.20
90	114.45	53.36	0.14	90	4.03
120	124.5	60.79	0.12	60	4.15
Response	L**	L**	L**	Q*	L**

Linear (L) or quadratic (Q) effects non significant (NS) or significant at P = 0.05(*), 0.01 (**)

Peduto (1998) reported that nitrogen plays a very important role in cell division. Therefore the increase in seedling height and leaf area might be due to high levels of nitrate, because plants absorb nitrogen as either ammonium (NH₄) ions or as nitrate (NO₃) ions. When nitrate levels are high, plants can accumulate nitrates in certain tissues above what is needed at that stage of growth.

Leaf area increased linearly with applied N, regardless of sampling date (Table 3.1). The highest increases in leaf area in response to applied N occurred between 0 to 30 mg·L⁻¹. Basoccu & Nicola (1992) observed the same results with pepper seedlings, where leaf area increased with increasing N rates from 20 to 150 mg·L⁻¹ levels. Similarly, Karchi & Cantliffe (1992) observed that the increase in leaf area of lettuce seedlings was related to increased N from 58 to 292 mg·L⁻¹, in the nutrient solutions.

Increasing nitrogen from 0 to 90 mg·L⁻¹ improved pulling success from 25% to 90 % and decreased when N application was 120 mg·L⁻¹.

At 35 DAS, leaf tissue N increased linearly from about 0.43 to 4.15 mg·kg⁻¹ with applied N (Table 3.1). This result is comparable to that of Soundy *et al.* (2001) in which plants grown with 100 mg·L⁻¹ N had 31.8 g·kg⁻¹ N in the leaves than did those grown with 60 mg·L⁻¹ (24.7) g·kg⁻¹.

There was a linear decrease in root:shoot ratio from 0.88 to 0.19 in transplants sampled 21 DAS; from 0.94 to 0.14 in those sampled 28 DAS and from 0.99 to 0.12 to those sampled at 35 DAS. The largest RSR values were obtained with 0 N (Table 3.1). Soundy *et al.* (2001) observed the same results where seedlings grown with 60 mg·L⁻¹ N had larger root: shoot than those grown with 100 mg·L⁻¹ N. Basoccu & Nicola (1995) reported that the root: shoot ratio decreased as N level increases.

The results indicated that there was a quadratic increase in relative growth rate from 0.45 to 0.92 mg·mg⁻¹·wk⁻¹ in transplants sampled 28 DAS and from 0.19 to 0.76 mg·mg⁻¹·wk⁻¹ in transplants sampled 35 DAS (Table 3.2). These results confirmed Nicola & Basoccu's (2000) results where, RGR increased in asparagus transplants grown with increased N concentration in the nutrient solution with a maximum value at 60 mg·L⁻¹ N.

Net assimilation ratio decreased quadratically to applied N (Table 3.2). For plants sampled 28 DAS NAR was greater with 0 N, but the total production of dry matter during the same period was greater when any level of N was applied. Similar results were observed with tomato seedlings where NAR decreased curvilinearly with increasing N rate (Basoccu & Nicola, 1995). Nicola & Basoccu (2000) also observed

the same results, with asparagus where NAR values decreased curvilinearly as N supplied increased.

Table 3.2 Influence of N nutrition on growth characteristics of lettuce transplants, July/August 2004

N applied (mg·L⁻¹)	Relative growth rate (mg·mg⁻¹·wk⁻¹)	Net assimilation rate (mg·cm⁻²·wk⁻¹)	Specific leaf area (cm²·mg⁻¹)	Leaf area ratio	Leaf Mass ratio	Root mass ratio
<i>21 Days After Sowing</i>						
0			0.31	0.16	0.53	0.47
30			0.57	0.43	0.75	0.25
60			0.60	0.47	0.78	0.22
90			0.56	0.44	0.79	0.20
120			0.59	0.49	0.84	0.16
Response			Q**	Q**	L**	L**
<i>28 Days After Sowing</i>						
0	0.45	3.28	0.22	0.11	0.52	0.48
30	0.89	2.11	0.52	0.41	0.79	0.20
60	0.91	1.96	0.56	0.46	0.82	0.18
90	0.89	2.02	0.53	0.44	0.84	0.16
120	0.92	1.92	0.54	0.47	0.87	0.13
Response	Q**	Q**	L**	Q**	L**	L**
<i>35 Days After Sowing</i>						
0	0.19	1.75	0.21	0.11	0.50	0.49
30	0.72	1.92	0.46	0.35	0.76	0.24
60	0.74	1.54	0.60	0.49	0.83	0.17
90	0.72	1.51	0.57	0.50	0.88	0.12
120	0.76	1.49	0.61	0.54	0.89	0.10
Response	Q**	L**	L**	Q*	L**	L**

Linear (L) or quadratic (Q) effects non-significant (NS) or significant at P = 0.05(*), 0.01 (**)

Specific leaf area increased quadratically in response to applied N for plants sampled 21 DAS. For plants sampled 28 and 35 DAS SLA increased linearly with applied N. Leaf area ratio increased quadratically with applied N rate (Table 3.2). Lowest SLA and LAR values were obtained with 0 N. The reduction in the SLA and LAR values for plants grown with 0 N reflects the reduction in both leaf size and assimilate production. This result confirmed the results of Nicola & Basoccu (2000) where, LAR values curvilinearly increased as N rate increased, reaching their maximum between 30 and 60 mg·L⁻¹ N levels.

Leaf mass ratio increased linearly for plants sampled 21, 28 and 35 DAS in response to applied N. The highest LMR value were obtained with 0 mg·L⁻¹ N. Root mass ratio decreased linearly for plants sampled 21, 28 and 35 DAS in response to applied N. the lowest RMR values were observed with 0 mg·L⁻¹ N (Table 3.2). The reduction in RMR might be due to high nitrogen application. Nicola & Basoccu (2000) observed the same results where leaf weight ratio showed a linear increase with increasing N and decreasing with a curvilinear trend in root weight ratio.

3.4 CONCLUSIONS

The experimental results showed that high N promoted leaf and shoot development, causing a concomitant decrease in root growth. This suggests that nitrogen concentration in the nutrient solution is fundamental to produce well-grown transplants. Nitrogen is a deciding factor of plant growth. It is the basis of proteins and without it plants could not live. The more nitrogen the plant receives the healthier the stems and leaves will be. The less nitrogen a plant receives the yellower and smaller it will be (Peduto, 1998).

The more nitrogen the plant receives the healthier the stems and leaves will be. The less nitrogen a plant receives the yellower and smaller it will be. However, the element allows for vigorous seedling growth, hence it should be dosed properly to avoid excessive shoot growth. This study indicated that N concentration could be increased up to 90 mg·L⁻¹, without causing an efficiency dropping in plant growth rates. Nitrogen at 120 mg·L⁻¹ improved the response of shoot growth, plant height

and leaf area, but adversely affected root growth. Therefore for media low in N, applying 90 mg·L⁻¹ N resulted in improved root and shoot growth, leading to improved plant pulling success at 35 DAS and resulting in high quality transplants.

The potential danger of nutrient stressing transplants has been known for over 50 years. Dufault (1998) stated that, “ any method used which results in stunning or hardening young seedlings permanently slows up their field performance, probably decreasing the yield roughly in proportion to the severity of the hardening treatment”. There is a need for further research on the long-term effect of vegetable transplant nutrition. This research will enhance our understanding of root and shoot growth dynamics in the greenhouse post-planting transplant shock, and shoot recovery in the field.

3.5 SUMMARY

Several levels of N were supplied via floatation irrigation to “Avirum” lettuce (*Lactuca sativa* L.) transplants to investigate the response of shoot and root growth of lettuce transplants to nitrogen nutrition. Plants were fertigated by floating flats with a nutrient solution containing N at 0, 30, 60, 90 and 120 mg·L⁻¹. The experiment was laid out as a randomised complete block design with four replications.

Transplants produced with 0 N grew poorly, regardless of sampling date. However, nitrogen at 120 mg·L⁻¹ improved the response of plant height, leaf area and shoot growth, but adversely affected root growth. In general, relative growth rate was improved, while net assimilation rate was reduced as N level increased. Root: shoot ratio decreased while, specific leaf area and leaf area ratio increased with applied N. Leaf mass ratio was improved, while root mass ratio was reduced as N rate increased. Only 25% of the plants produced without N could be pulled from the seedling trays, whereas 90% could be pulled when 90 mg·L⁻¹ N was added. This work suggests that at least 90 mg·L⁻¹ N, supplied via floatation irrigation, was required to produce a quality transplant.

GENERAL DISCUSSION AND CONCLUSIONS

All over the world, efforts are made to produce crops in the most economically profitable way; the same applies to vegetable crops. Lettuce is one of the most economically important agricultural crops. The challenge is to manage inputs in a way that will give better returns to the farmer. One of the most important inputs in vegetable production is variety selection, particularly as it relates to yield. Selection of a nutritional regime to grow vegetable transplants is also one of the important aspects of vegetable production. The objectives of this study were to evaluate the performance of different crisphead cultivars in relation to yield and quality performance and to investigate which level of nitrogen could produce high quality transplants.

Vegetable growers face a daunting challenge in variety selection: there sometimes are hundreds of varieties of lettuce and the mix of varieties constantly changes. To help producers meet this challenge, a crisphead lettuce variety trial was conducted with fifteen cultivars.

Since performance is affected by many factors such as daily temperature cycles and soil moisture availability, at least four seasons of study are needed to scientifically identify Pretoria's top-performing varieties. This study has identified the best performing crisphead cultivars in one season (autumn).

Commercial growers require that heads of lettuce meet certain requirements in size, shape and weight. Dual Purpose, Great Lakes, Mohawk and Victory were essentially the only cultivars on test that were observed to have good quality production characteristics to meet this criterion. Del Rio was the best disease resistant cultivar producing 100% of marketable heads. Great Lakes and Cannon matured earlier compared to the rest of the cultivars, at 60 days after transplanting.

The results indicated that two crisphead lettuce cultivars, Taina and Great Lakes 659 are late maturing types. The maturity was delayed by eleven days as indicated in Chapter 4 and their head sizes was very small, which can be considered undesirable

for commercial use. However, they might be suitable for markets that sell individually wrapped lettuce or they might be suitable to be grown as baby lettuce.

In conclusion, the following cultivars can be grown in Pretoria's environment: Dual Purpose, Great Lakes, Mohawk, Victory and Del Rio. However, as this is an observational trial only, results from this trial should not be considered definitive, but rather should be interpreted in the context of expected on-farm performance. That is, known differences between conditions at this experimental site and a specific farm situation should be considered. Differences in visual appearance that might influence buyer acceptance were not quantitatively evaluated in this trial. These subjective considerations, in conjunction with results from this variety trial provide valuable information to assist growers in identifying superior varieties.

Seed companies will continue to offer new varieties therefore; continuous cultivar testing is necessary under any conditions as new cultivars are appearing at a fast rate.

Selection of a nutritional regime to grow a specific vegetable transplant crop depends on requirements of the transplant grower and the farmer who buys the transplants. Nitrogen is a deciding factor of plant growth. The more nitrogen the plant receives the healthier the stems and leaves will be. The less nitrogen a plant receives the yellower and smaller it will be (Peduto, 1998). This study sought to investigate the response of shoot and root growth of lettuce transplants to nitrogen nutrition. To achieve this objective five different concentrations of nitrogen were used: 0, 30, 60, 90 and 120 mg·L⁻¹.

Transplants produced with 0 N grew poorly, regardless of sampling date. However, nitrogen at 120 mg·L⁻¹ improved the response of plant height, leaf area and shoot growth, but adversely affected root growth. In general, relative growth rate was improved, while net assimilation rate was reduced as N level increased.

Root:shoot ratio decreased with applied N. The highest root:shoot ratio resulted from 0 N, regardless of the sampling date. Both specific leaf area and leaf area ratio increased with applied N. Lowest SLA and LAR values were obtained with 0 N. The

reduction in SLA and LAR values for plants grown with 0 N reflects the reduction in both leaf size and assimilate production. Leaf mass ratio was improved, while root mass ratio was reduced as N rate increased. At 30 mg·L⁻¹ N, root growth was improved resulting to high-quality transplants. Transplants grown with 0 N were inferior to those plants grown with any other level of N since pulling was difficult as shown in Chapter 4. Only 25% of the plants produced without N could be pulled from the seedling trays, whereas when N was added pulling success was 60% with 30 mg·L⁻¹, 65% with 60 mg·L⁻¹, 90% with 90 mg·L⁻¹ and 60% with 120 mg·L⁻¹. The best pulling success percentage was observed with 90 mg·L⁻¹ N.

Nitrogen concentration in the nutrient solution is fundamental to produce well-grown transplants. The element allows for vigorous seedling growth, hence it must be dosed properly to avoid excessive shoot growth. This study confirms the importance of high nitrogen fertilisation in the nursery or greenhouse. The nutrient solution can be increased up to 90 mg·L⁻¹ N without causing an efficiency dropping in plant growth rates.

Nitrogen is extremely important for the production of proteins and is also part of the DNA molecule, thus it promotes leaf and stem growth. Low nitrogen levels can result in slow growth and poor development of transplants (Peduto, 1998).

Plants that receive too much nitrogen will grow so rapidly that they will be weak and spindly. Thus, a shortage of nitrogen will cause the plant to mobilize extra nitrate stored in older tissue. Therefore optimum nitrogen rate (90 mg·L⁻¹) is recommended for healthy transplants.

Nutrition of transplants should include field testing that evaluates transplant shock and pre-harvest growth (yield and quality). Thus, there is a need for continuous research on the long-term effect of vegetable transplant nutrition.

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APPENDICES

APPENDIX A: GREENHOUSE EXPERIMENT

Table A1 Analysis of variance for root and shoot characteristics of lettuce transplants as affected by N nutrition (July/August), 2004

Source	DF	Mean Squares ^z						
		Fresh shoot mass (mg 10 ³)	Dry shoot mass (mg)	Fresh Root mass (mg 10 ¹)	Dry root mass (mg)	Plant height (mm 10 ²)	Leaf area (cm ²)	Root: shoot ratio 10 ⁻²
<i>21 Days After Sowing</i>								
Treatment	4	43.18 ^{**}	134.75 ^{**}	50.79 ^{**}	1.48 ^{**}	1321.68 ^{**}	54.09 ^{**}	31.30 ^{**}
Rep	3	0.01 ^{NS}	0.10 ^{NS}	0.05 ^{NS}	0.06 ^{NS}	38.24 ^{NS}	0.09 ^{NS}	0.24 ^{NS}
Error	12	0.03	1.31	1.58	0.45	120.68	1.56	0.03
<i>28 Days After Sowing</i>								
Treatment	4	401.14 ^{**}	1088.9 ^{**}	524.98 ^{**}	8.69 ^{**}	3434.29 ^{**}	359.02 ^{**}	44.93 ^{**}
Rep	3	4.43 ^{NS}	2.66 ^{NS}	0.12 ^{NS}	0.03 ^{NS}	7.8 ^{NS}	0.31 ^{NS}	0.25 ^{NS}
Error	12	28.39	19.2	0.58	0.63	31.47	2.79	0.03
<i>35 Days After Sowing</i>								
Treatment	4	2407.83 ^{**}	5732.39 ^{**}	2362.66 ^{**}	72.65 ^{**}	6637.69 ^{**}	2308.64 ^{**}	53.49 ^{**}
Rep	3	0.23 ^{NS}	0.93 ^{NS}	0.19 ^{NS}	0.24 ^{NS}	1.17 ^{NS}	0.52 ^{NS}	0.03 ^{NS}
Error	12	25.72	12.92	3.88	1.4	5.08	10.93	0.003

^z F-value significant (*) at 5% or highly significant (**) at 1% level of probability

Table A2 Analysis of variance for the influence of N nutrition on growth characteristics of lettuce transplants (July/August), 2004

Source	DF	Mean Squares ²								
		Relative growth rate mg·mg ⁻¹ ·wk ⁻¹	Net Assimilation rate mg·cm ⁻² ·wk ⁻¹	Specific area cm ² ·mg ⁻¹	leaf ratio	Leaf area mass ratio	Root mass ratio	Pulling Success (%)	Leaf tissue N g·kg ⁻¹	
<i>21 Days After Sowing</i>										
Treatment	4			60.60**	71.87**	57.27**	57.27**			
Rep	3			1.03 ^{NS}	0.24 ^{NS}	0.3 ^{NS}	0.3 ^{NS}			
Error	12			8.74	4.74	2.63	2.63			
<i>28 Days After Sowing</i>										
Treatment	4	168.93**	132.37**	79.92**	90.65**	84.17**	84.17**			
Rep	3	0.38 ^{NS}	0.82 ^{NS}	0.221 ^{NS}	0.04 ^{NS}	0.21 ^{NS}	0.21 ^{NS}			
Error	12	14.35	28.54	3.27	17.3	1.95	1.95			
<i>35 Days After Sowing</i>										
Treatment	4	238.07**	14.06**	111.02**	130.06**	103.19**	103.19**	2150**	10**	
Rep	3	1.25 ^{NS}	3.74 ^{NS}	0.51 ^{NS}	0.18 ^{NS}	0.04 ^{NS}	0.04 ^{NS}	106.67 ^{NS}	0.05 ^{NS}	
Error	12	18.1	341.13	3.05	52.07	0.33	0.33	4680	0.63	

² F-value significant (*) at 5% or highly significant (**) at 1% level of probability

APPENDIX B: FIELD EXPERIMENT**Table B1 Analysis of variance for quality characteristics of fifteen crisphead cultivars**

Source	DF	Mean Squares ^z					
		Head mass (mm)	Head height (mm)	Head diameter (mm)	Stem height (mm)	Stem diameter (mm)	Core ratio
Cultivars	14	1.94 ^{**}	2.98 ^{**}	2.49 ^{**}	3.19 ^{**}	2.99 ^{**}	5.25 ^{**}
Rep	3	3.49 ^{NS}	1.04 ^{NS}	1.59 ^{NS}	0.37 ^{NS}	1.39 ^{NS}	0.07 ^{NS}
Error	42	0.47	0.29	0.42	0.27	0.25	0.06

^z F-value significant (*) at 5% or highly significant (**) at 1% level of probability