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Organic Tomato Production:
An attempt to improve production by transplant and early watering

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Preface

In 2003, I was given the chance to study abroad as part of the Socrates-Erasmus exchange student programme of the EU. One of my first choices was Denmark and KVL (Royal Veterinary and Agricultural University) due to its good reputation and after the suggestion of prof. Ioannis Vlachos from the international office of my home university (Technological Educational Institute of Crete -TEI). The profit of the experience was immense both at an academic as well as at a personal level. Since the beginning of the course, I was amazed by the environment, the teaching methods and the responsible way of work.

Returning home, I knew that KVL would be my 1st choice in order to complete a practical training along with the composition of a thesis for my degree. I applied for the Leonardo DaVinci programme and I was accepted at the Crop Science department under the general supervision of prof. Jesper Mazanti Aaslyng, whom I thank for all his help and the chance to work with him. Moreover, I would like to express my gratitude to my supervisor prof. Oliver Körner, whose help, guidance, comments, patience and psychological support, were priceless; without him the thesis would have never been completed.

Nevertheless, a few more people played an important role in the composition of the present thesis; prof. Dvorlai Wullfson, for the numerous hours she spent with me, introducing and explaining me the Leaf Area measurement technique and principles, Mr. Klaus Sogard the producer, who kindly shared both plants and ideas qith me and prof. Marco Sciortino for letting me use his thesis. A special thanks to Andrea Andreassen for her help and psychological support when things were not so good. Lastly, this thesis would not have been accepted, presented for my home university without the help and patience of prof. Emmanouil Kabourakis, my Greek supervisor, whom I owe a big part of my organic farming knowledge.

Moreover, I would like to thank my 'danish' family; my 'brother' Alessandro, for his priceless friendship and endless support, along woth our friend Mauda! My flatmates Alan, Andre, Algimantas, Batista, Giedre, Jose, Katarzyna, Monika, Raimundo and Vladimir, for the friendship, companionship and moments that offered me- thank you guys! Lastly, I thank my Greek friends who did not come and visit me, allowing me to finish my thesis undisturbed.

Summary

Since the beginning of the 19th century, tomato has become very popular and due to its wide adaptation, it is now cultivated throughout the world. Previous years' food scandals promoted the market of the organic food products, including tomatoes. However, the organic tomato production still remains low, although the estimations concerning the demand trend show a steady increase. Therefore, in order to achieve the best feasible yield, some parameters need to be altered.

The yield of organic tomato is thought to be lower compared to the conventional one, although some objections are raised. The reasons are still indistinct, but some parameters can be changed to alleviate the situation; the transplant stage and the early watering schedule. Until recently, later transplant, although there was no literature feed-up to support it, was thought to lead in higher net returns, whereas the early ones to vegetative growth. Moreover, the watering was mainly based on guessing, without any experimentation and the right water quantity that tomato plants need. Based upon, the lack of experimentation on these two parameters, the present thesis focus on the right transplant stage and tries to evaluate the different irrigation schedules, so as ultimately to suggest the plan that will have the highest net returns.

Experiment's set up was in a greenhouse of KVL, Taastrup, Denmark. Tomato plants (cv. 'Aromata') were purchased and planned to be transplanted on 4 different stages, according to the number of trusses flowering; pre-flowering, first, second and third truss flowered. Moreover, four different watering schedules were planned: i) 100 ml, ii) 180 ml, iii) 250 ml and iv) 350 ml per plant each watering. Although, a problem occurred and eventually only 2 out of the 4 different transplanting dates took place, the experiment was completed with satisfying results, which proved the initial hypothesis.

In brief, the thesis' results demonstrate that the plants, which had their first truss flowered had more increased yield than those that were transplanted immediately. Moreover, the total weight and the fruit number were also higher, without any alterations in the fruit's diameter, the incidence of blossom-end rot or non-commercial shape. The differences in the vegetative growth between the two transplant stages were mainly based on the dry weight of plants, which showed that later transplanted plants caused reduced dry weights. In addition, as far as the watering schedules are concerned, the larger volumes resulted in a higher fruit set, along with a vegetative production in both transplant stages, whereas the lower water quantities in a smaller production, consisting of shorter and more fragile plants. Furthermore, the latter plants had increased concentrations of total soluble solids in their fruits, an attribute that has important role in the taste.

All these results are an initial effort which needs further research and longer experimentation period, so as to produce more detailed outcomes. Still they can be adopted by commercial producers who are willing to try new methods, both for increasing as well as improving their yield. Especially in countries, where the environmental conditions are not ideal, the thesis' results may prove to be a useful pattern.

Περίληψη

Από τις αρχές του 19ου αιώνα, η τομάτα έτυχε ευρείας αποδοχής από του καταναλωτές παγκοσμίως και δεδομένης της προσαρμοστικότητά της, καλλιεργείται παντού ανά τον κόσμο. Τα διατροφικά σκάνδαλα των τελευταίων ετών έδωσαν ώθηση στην αγορά και κατ' επέκταση στην καλλιέργεια βιολογικών προϊόντων διατροφής, συμπεριλαμβανομένων και της τομάτας και των προϊόντων της. Ωστόσο, τα επίπεδα παραγωγής βιολογικής τομάτας παραμένουν χαμηλά, αν και υπάρχουν ενδείξεις που φανερώνουν τη σταθερή αύξηση της ζήτησης της ως προϊόν. Η απόδοση της βιολογικής καλλιέργειας συγκριτικά με αυτής της συμβατικής καλλιέργειας της τομάτας θεωρείται γενικώς χαμηλότερη, αν και υπάρχουν διαφωνίες σχετικά με αυτή την άποψη. Οι λόγοι που οδηγούν σε μειωμένες αποδόσεις στην βιολογική καλλιέργεια της τομάτας δεν είναι σαφείς, αλλά υπάρχουν κάποιες παράμετροι όπως το στάδιο μεταφύτευσης των σποροφύτων και η πρώιμη άρδευση, που αν τροποποιηθούν θα μπορούσαν να συμβάλλουν στην βελτίωση των επιπέδων παραγωγής.

Ακόμα και σήμερα, παρά την απουσία σχετικής βιβλιογραφίας που να υποστηρίζει αυτήν την άποψη, επικρατεί η άποψη ότι η όψιμη μεταφύτευση επιτυγχάνει μεγαλύτερη απόδοση, ενώ αντίθετα η πρώιμη ευνοεί την βλαστική ανάπτυξη. Επιπλέον, η άρδευση βασίζεται κυρίως σε εμπειρικές παρατηρήσεις όσον αφορά την ποσότητα του νερού άρδευσης που απαιτείτε, λόγω απουσίας σχετικής πειραματικής έρευνας. Λαμβάνοντας, λοιπόν, υπόψη την έλλειψη πειραματισμού στις δύο αυτές παραμέτρους, η παρούσα πτυχιακή εργασία επικεντρώθηκε στην μελέτη τους. Το πειραματικό μέρος περιλαμβάνει την αξιολόγηση διαφορετικών σταδίων μεταφύτευσης και παράλληλα την εφαρμογή διαφορετικών επιπεπέδων νερού άρδευσης, με απώτερο στόχο τη δημιουργία ενός καλλιεργητικού σχεδίου το οποίο θα μπορούσε να βελτιώσει ποιοτικά και ποσοτικά την παραγωγή της βιολογικής τομάτας.

Οι πειραματικές εργασίες πραγματοποιήθηκαν στις εγκαταστάσεις του Βασιλικού Γεωπονικού Πανεπιστημίου της Δανίας (KVL). Χρησιμοποιήθηκαν φυτά τομάτας (cv. 'Aromata') τα οποία μεταφυτεύθηκαν σε συγκεκριμένα στάδια ανάπτυξης, με κριτήριο τα ανθισμένα άνθη της ανθοταξίας τους, και πιο συγκεκριμένα σε τέσσερα στάδια ανάπτυξης που καθορίστηκαν με κριτήριο: αν είχαν ανθισμένα άνθη σε καμία, στην πρώτη, δεύτερη ή τρίτη ανθοταξία. Επιπλέον, εφαρμόστηκαν 4 διαφορετικά επίπεδα άρδευσης: i) 100 ml, ii) 180 ml, iii) 250 ml και iv) 350 ml ανά φυτό σε κάθε πότισμα. Παρόλο όμως που τελικά μόνο 2 από τις

σχεδιασμένες μεταφυτεύσεις πραγματοποιήθηκαν, τα αποτελέσματα της εργασίας ήταν άκρως ικανοποιητικά, επιβεβαιώνοντας την αρχική υπόθεση.

Συνοπτικά τα αποτελέσματα της εργασίας έδειξαν, ότι τα φυτά που κατά τη μεταφύτευση τους είχαν ήδη ανοιχτά άνθη, έδωσαν υψηλότερη παραγωγή σε σύγκριση με εκείνα χωρίς άνθη. Επιπλέον, το συνολικό βάρος και ο αριθμός των φρούτων ήταν επίσης μεγαλύτερος, χωρίς να παρατηρηθούν διαφορές στη διάμετρο των φρούτων, το φαινόμενο της ξηρής σήψης της κορυφής των καρπών (blossom-end rot) ή στο μη εμπορεύσιμο σχήμα καρπών. Η διαφορά της βλαστικής ανάπτυξης, ανάμεσα στα δύο στάδια μεταφύτευσης, εκτιμήθηκε μέσο του ξηρού βάρους των φυτών, που έδειξε ότι τα όψιμα μεταφυτευμένα φυτά είχαν μικρότερο ξηρό βάρος και άρα μικρότερη βλαστική ανάπτυξη. Σχετικά με την άρδευση, τα φυτά που λάμβαναν μεγαλύτερες ποσότητες νερού, είχαν μεγαλύτερη καρποφορία και βλαστική ανάπτυξη, ανεξάρτητα σταδίου μεταφύτευσης. Αντίθετα, η μικρότερη ποσότητα νερού οδήγησε σε μειωμένη παραγωγή και χαμηλή ανάπτυξη των φυτών. Τέλος, τα όψιμα φυτά είχαν μεγαλύτερη συγκέντρωση ολικών διαλυτών στερεών στους καρπούς τους, που αποτελούν ένα παράγοντα που επηρεάζει σημαντικά στη γεύση.

Όλα τα συμπεράσματα που προκύπτουν συνιστούν μια πρώτη προσπάθεια μελέτης ενός θέματος το οποίο χρήζει περαιτέρω έρευνας και πειραματισμού, με σκοπό να οδηγηθούμε σε πιο συγκεκριμένα και λεπτομερή συμπεράσματα. Παρ' όλα αυτά, τα αποτελέσματα μπορούν να υιοθετηθούν από παραγωγούς που επιθυμούν να πειραματιστούν με νέες μεθόδους που στοχεύουν στην αυξηση και βελτίωση της παραγωγής τους. Ιδιαίτερα σε χώρες, όπου οι κλιματολογικές συνθήκες δεν είναι οι βέλτιστες για την καλλιέργεια της τομάτας, τα αποτελέσματα της εργασίας μπορεί να αναδειχθούν σε ένα πολύτιμο εργαλείο.

1.1 Tomato

1.1.1 Historical background

The name 'tomato' derives from the Mexican- Indian word "tomatl" (Sahadevan, 1987, Harvey *et al*., 2002). It originates from the Andean region of South America, in an area that is covered by parts of Bolivia, Chile, Ecuador, Colombia and Peru. Archaeological and circumstantial evidence (great range of diversity) show that the tomato was domesticated in Mexico (Opña and Vossen, 1993, Hanelt, 2001, Bose *et al*., 2002, Jones, 1999). Furthermore, it is suggested that the large fruited varieties, that are cultivated nowadays, descend from the primitive cherry tomato, *Lycopersicon esculentum* var. *cerasiforme* (Dunal) (Opña and Vossen, 1993, Hanelt, 2001, Bose *et al*. 2002).

In Europe, the tomato was introduced after the discovery of the American continent. It arrived at an advanced level of domestication from Mexico, where people have been cultivating it for centuries. However, tomato's reputation as a poisonous fruit, probably mistaken due to its relativeness to the deadly nightshade, deterred its consumption and was cultivated only because of curiosity. Since its non-toxic characterization, in the beginning of the 19^{th} century, tomato becomes very popular. Nowadays, it is one of the most important vegetables in the world (Opña and Vossen, 1993, Jones, 1999, Harvey *et al*., 2002).

1.1.2 Botanical characteristics

Tomato's botanical name is *Lycopersicon esculentum* (Mill.). Other names in which the tomato is referred to, in bibliography are; *Solanum lycopersicum* (L.), *L. lycopersicum* (Karst.), *S. pseudolycopersicum* (Jacq.), *L. solanum* (Medik.) (Opña and Vossen, 1993, Hanelt, 2001). It belongs to the Solanaceae or nightshade family and in the genus *Lycopersicon.* The genus includes 12 species, all native to South America. The genus differs from *Solanum* mainly in the way that they release the pollen and the colours of their flowers. (Bose *et al*., 2002).

In 1949 tomatoes were classified into two species*, L. esculentum* and *L. pimpinellifollium*, with 5 botanical varieties in *L. esculentum* var. *commune* (common tomato), var. *grandifolium* (large leafed tomato), var. *validum* (upright tomato), var. *cerasiforme* (cherry tomato) and var. *pyriforme* (pear tomato). Late reviewed taxonomy and phylogeny of the genus *Lycopersicon* has recognised 9 species: *L. esculentum, L. pimpinellifolium, L. cheeswmanii, L. hirsitum, L.*

pennellii, L. chmielewskii, L. parviflorum, L. peruvianum and *L. chilense*, comprising of various botanical varieties and forms. (Bose *et al*., 2002).

1.1.3 Nutritional value and uses

Tomato has an important role in the human nutrition not only because of its remarkable nutritive value, but also due to the overall consumption in comparison with other vegetables. Tomato's nutritive value is shown at the following table (1.1):

Table 1.1: Composition of tomato fruit (per 100g of edible fruit)*

Moisture	93,1 g	Vitamin A	320 I.U.
Protein	1,9 g	Thiamine	0.07 mg
Fat	0,1 g	Riboflavine	0.01 mg
Minerals	0,6 g	Nicotinic acid	0,4 mg
Fibre	0,7 g	Vitamin C	31 mg
Carbohydrates	3,6 g	Calcium	20 mg
Sodium	45,8 mg	Magnesium	15 mg
Potassium	114 mg	Oxalic acid	2 mg
Copper	0,19 mg	Phosphorus	36 mg
Sulphur	24 mg	Iron	1,8 mg
Chlorine	38 mg		

* reproduced by Bose *et al.* (2002)

As the above table shows, tomatoes are a rich source of vitamins A and C. Both vitamins increase in quantity, when the fruits are allowed to ripen on the vine. Immature fruit contain the alkaloid tomatine, which declines as the fruit matures, giving its place to lycopene and carotine, substances on which the red colour of tomatoes is attributed, making the fruits edible (Opña and Vossen, 1993, Bose *et al*., 2002). The seeds contain 24% of semi-drying edible oil and can be used as salad oil and in the manufacture of margarine, used in south and south-east Asia (Opña and Vossen, 1993, Bose *et al*., 2002).

According to Bose *et al*., (2002) tomatoes are also referred to have medicinal value; the pulp and juice are digestible and can help the human organisation as mild aperients, promoters of gastric secretion and blood purifiers. Furthermore, it is reported to have antiseptic properties against intestinal infections (Bose *et al*., 2002). It is also said to be useful against the mouth cancer, sore mouth and others (Bose *et al*., 2002). All these properties are possibly attributed to lycopene, a powerful antioxidant that is contained in the tomato fruit. Generally, it is thought to be a vegetable that helps our stomach to stay healthy (Bose *et al*., 2002, Jones, 1999, Harvey *et al*., 2002).

The fruits, that vary in size, shape and colour among varieties, can be eaten raw -fresh (salads) or cooked in numerous ways, solely or as ingredient for adding colour or flavour to the food. In addition, tomatoes in bulk, are used commercially, in processed forms such as purées, juice, sauces, ketchup, canned whole or diced fruits. Green tomatoes are also used for pickles, preserved in vinegar or brine. (Opña and Vossen, 1993, Hanelt, 2001, Bose *et al*., 2002, Harvey *et al*., 2002).

1.1.4 Around the world

Nowadays, because of its wide adaptation and variation, tomato is extensively cultivated either outdoors or indoors (Opña and Vossen, 1993, Hanelt, 2001, Bose *et al*., 2002, Harvey *et al*., 2002). The estimated world production is about 90 million tonnes on about 31700 ha (Bose *et al*., 2002). The largest producer is China with estimated production of 16.4 million tonnes, placing USA to second place (Bose *et al*., 2002).

Within the European regional scale, there is a great difference between North and South; the production of northern Europe takes place under glass in highly controlled atmospheres with high net returns, whereas the southern Europe's is either open-field or plastic-covered with low cost (Harvey *et al*., 2002). But this is not the only difference; the consumption varies from country to country; surveys of how many fresh tomatoes per capita were eaten each day for a whole year on average show, that Greeks are at the top (Figure 1.1). Every single Greek person eats over six tomatoes daily! Probably this is attributed to the different perception of what people consider fresh and the different use of them. That level of consumption is about 20 times greater than in The Netherlands, although the country is the largest producer and exporter of fresh tomatoes amongst Northern countries (Harvey *et al*., 2002).

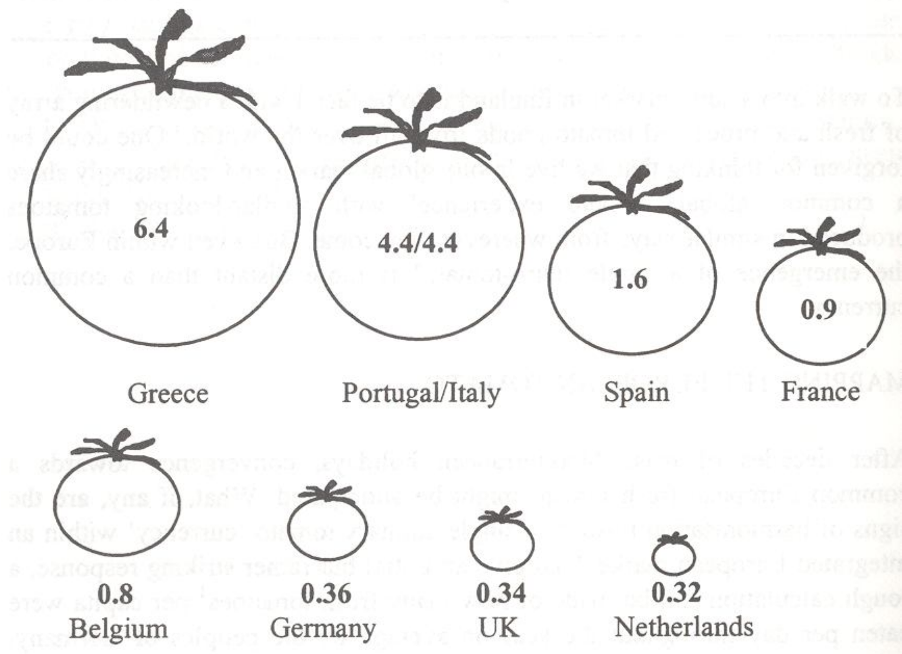


Figure 1.1: Per capita consumption of number of fresh tomatoes eaten per day in various European countries (1998 data). (Taken from Harvey M. *et al.*, 2002)

1.2 Organic tomato

1.2.1 Organic wave

In the previous years a number of serious food scandals such as the mad cow disease and the dioxin, rapidly promoted the market for organic food (Baringdorf, 2000, Scandurra, 2000, Regouin, 2000). Consumers trust the organic products and regard them as trustworthy (Baringdorf, 2000). Therefore, in recent years, the demand for organically grown foods has increased and the demand exceeds the supply (Dabbert *et al*., 2004, Haen, 2000). According to 2000's data, the sales of organic foods were estimated on 1 to 2% of the total food sales (Haen, 2000, Scandurra, 2000). Although, this number might seem low, the growth trend of the last decade has been impressive (Dabbert *et al*., 2004, Haen, 2000).

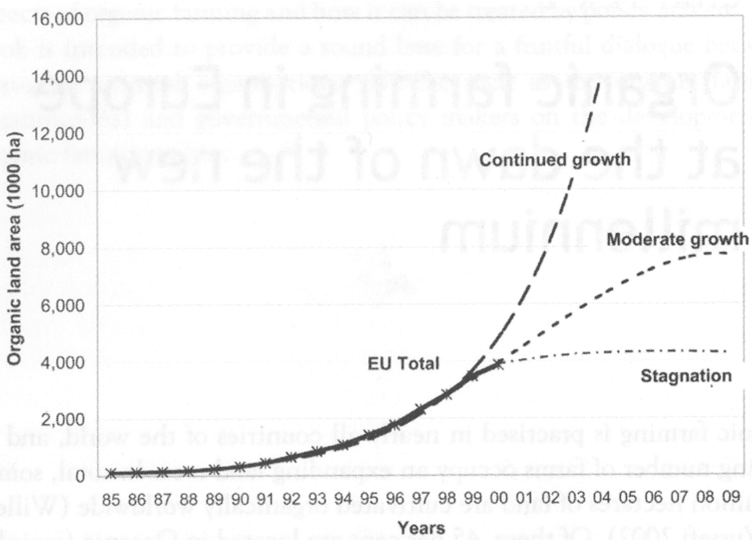


Figure 1.2: The development of organic farming in the European Union (taken from Dabbert *et al.*, 2004).

Within European agriculture, organic farming follows an increasing trend (Dabbert *et al.*, 2004). The development of the last years gives a prediction on future trends but, whether the same dynamic course continues or reached its maximum peak, only assumptions can be made (Figure 1.2) (Dabbert *et al*., 2004). Organic food sales for the year 2006 could vary from 5 to 10% of total food sales (Scandurra, 2000). Moreover, taking into account either the per capita consumption or the organics as a percentage of total food sales, the surveys reveal that Denmark, Switzerland and Austria (Figure 1.3) lead the charts. On the other hand, Germany holds the sceptres as the largest organic consumer market (Dabbert *et al*., 2004, Kortbech-Olesen, 2000, Scandurra, 2000). Another interesting statistic is that although organic products are, in general, more expensive compared to the conventional ones, consumers are willing to pay price premiums in their purchase (Dabbert *et al.*, 2004, Raunkjær, 2000). An extra amount of 15-18% to the standard price is considered reasonable by most consumers, while an increase of 25-30% at the price still seems to be affordable to the majority of consumers (Dabbert *et al.*, 2004). The greenhouse tomato growers cannot afford to ignore this opportunity.

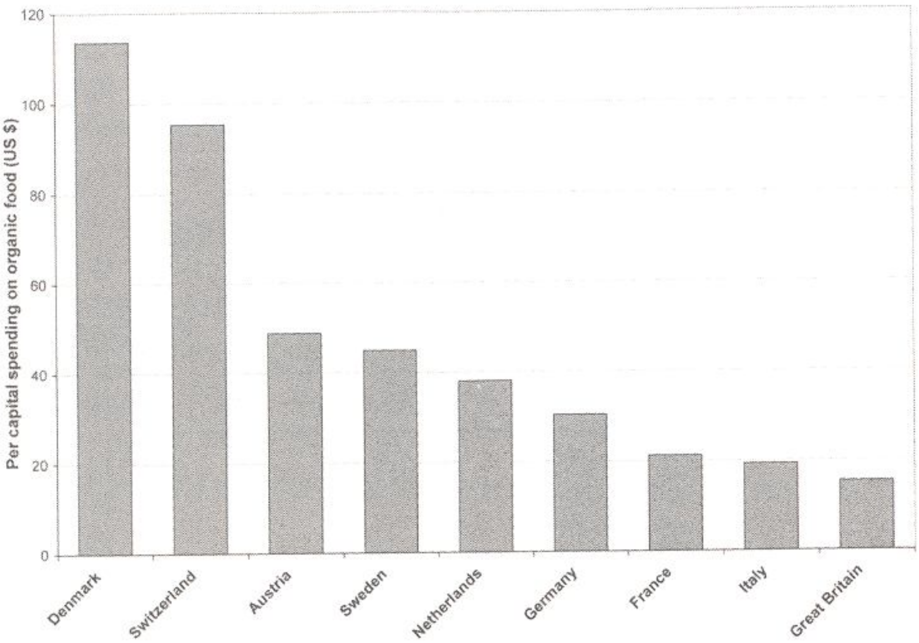


Figure 1.3: Estimated per capita spending on organic foods in 2000 by country. (taken from Dabbert *et al.*, 2004)

1.2.2 Preference to organic tomato

Organic tomatoes, as all organic fruits and vegetables, are often veiled in a myth of being of great merit in the aspect of quality in comparison with the conventionally grown ones (Dabbert *et al.*, 2004, Johansson *et al.*, 1999, Haen, 2000, Scandurra, 2000, Regouin, 2000). The concept of quality can be very subjective, as it largely depends on what the consumer thinks it is good or bad. However, studies and sensory analyses have shown that when information was given considering an organically grown product, the preference of consumers had a bias towards it (Dabbert *et al.*, 2004, Johansson *et al.*, 1999). The majority of consumers characterises the organic foods healthy and nutritious in consumption, therefore, they purchase them. Moreover, in the demand and choice of changing from conventionally to organically grown products, attributes of organic products such as environmental concerns and awareness, feeling of safety and better tasting (Dabbert *et al.*, 2004, Haen, 2000, Lenteren, 2000, Regouin, 2000), play a role, although relatively small (Johansson *et al.*, 1999). Although there is no scientific evidence that organic foods have any of the above-mentioned benefits, in contrast to the standards of the conventional ones (Haen, 2000), they influence the choice and market value on foods (Shewfelt and Brückner, 2000).

1.2.3 Current production situation analysis

Generally, the consumers find no difficulties in satisfying their needs for vegetables, as the natural variation in both organically and conventionally grown vegetables covers much the same variation in perceived product quality (Johansson *et al*., 1999).

Nevertheless, it is important to underline that the yield, an important determinant of the competitiveness of both farming systems, is generally assumed to be lower in organic than in conventional farming (Bhardwaj *et* al., 2000, Dabbert *et al*., 2004, Offermann and Nieberg, 2000). The manager of Markhaven Aps Odense, Denmark, Klaus Sogård, claims that he would expect higher yields; “Conventional tomato growers on the greater area have higher net yields”. Moreover, he believes that the organic practises should not be a constraint, an opinion that Nick Starkey, an advisor on organic farming (DEG GreenTeam, Denmark), also supports: “There is a 5-15% shift to fruit production that favours conventionally grown tomatoes towards organically ones”.

On the other hand, there are many who claim that due to the restricted information available, it is more difficult to draw a conclusion in vegetables, including tomatoes and no study-based explanation can confirm or deny this assumption (Offermann and Nieberg, 2000).

Moreover, an additional obstacle that producers meet at northern latitudes is the unfavourable climate of low natural light and short daylengths. For example, in Denmark, where the experiment took place, transplants for early heated tomato crops are produced in mid-winter under severely limited light conditions, when natural day lengths are short and light intensities low. In order to face the increasing demand for organic products, some parameters need to be adjusted. To alleviate this situation, many practises are found in use; delayed transplant, supplementary lighting, temperature or salinity are factors are used in transplant production to manipulate plant growth and development (McCall, 1996). But which are the factors that determine a “good” production? In order to answer this question an analysis of the parameters affecting the growth and development of tomato follows.

1.3 Parameters affecting the growth & development

Tomato's growth depends on numerous factors; variety, temperature, irradiance, irrigation, salinity, moisture and soil fertility are only few of them (Bose *et al.*, 2002, Jones, 1999, McCall, 1996, Singh, 1997). The majority of them has been examined thoroughly and many studies have been published (e.g. McCall, 1996, Jones, 1999, Bose *et al.*, 2002). The optimum temperature and light regime have been stated precisely for fruit production (Bertin, 2005). Re-examining all these factors, in favour of organic farming in one study and limited time, would be really difficult so, the objective of this thesis focuses on three parameters: the compost, the irrigation and the transplant stage, practices currently on use without an experimental or literature feed up.

"There are some factors that influence the production, that need to be examined in order to achieve the highest feasible net returns. These factors are the availability of nutrients, the right transplant stage and the early watering schedule. The nutrient problem is mainly focused on the amount of Nitrogen (N) that the tomatoes need. On the early stages, there are not any problems, due to the decomposition of the compost that is used. However, sometimes, the abundance of N together with the low light level, leads to overshooting in the beginning and then to a N deficiency –all the available N has already been uptaken by the plants. The late transplanting could be a solution but, it leads to feed problems, e.g. lack of potassium. That phenomenon is overcomed rather easily by placing the plants in the soil; symptoms go away in few days. This action may result in early transplanting and overshooting, by which the producer gets fooled – due to vegetative growth, increases the temperature, in order to control the growth and waters more often than needed –the watering is mainly based on guessing. Finally, the producer ends up with vegetative plants and an over wet soil, which will have long-time consequences" (Nick Starkey, personal communication).

These three factors, the compost, the irrigation and the transplant stage are analysed below for a deeper understanding of the present thesis. More specifically, the compost's paragraphs reveal the importance of a good prepared soil. Soil is a prerequisite for organically grown plants and its nature requires a special handling, compared to conventional or rock wool grown plants, where nutrients can be added easily and at low cost (Raviv *et al.*, 2004). Irrigation and transplanting are the main subjects that this thesis will focus on. The tomato is very sensitive to soil water regime, which is affected by a number of factors (Bose *et al.*, 2002), while a transplanting time is not well-documented. Within the following paragraphs, the current situation is presented indicating the way that they influence yield and where the flaws are.

1.3.1 Compost

Limitations in the production of organic tomato can derive from the fact that the demand for plant nutrients is very high and the availability of them rather limited (Bhardwaj *et al.*, 2000, Thorup-Kristensen *et al*., 2002). The amount of N that is needed for a tomato crop can be more than 200 g m^{-2}, which is roughly 20 times the amount needed for other field crops, eg. grain or leguminous crops and pome trees (Thorup-Kristensen *et al*., 2002). The normal level of N mineralization from the soil covers only a small portion of this, therefore, large quantities must be added. The main source of nutrients for organic growers is the animal manure (Thorup-Kristensen *et al*., 2002).

However, it is hard to acquire large quantities of organic manure. Moreover, in Thorup-Kristensen's (Thorup-Kristensen *et al*., 2002) report, is stated that organic manure is not in abundant in organic farming and only few organic dairy farms are situated in the areas, where the most of the greenhouse production occurs. At present, the needs in compost are covered by conventional origin manure, but this practise is against the basic ideas and rules of organic farming (Thorup-Kristensen *et al*., 2002).

Furthermore, manure must be composted before used. Although non-composted manure has larger amount of N content than the composted manure, the forms (NH_4^+, NO_x, N) of it are high soluble, resulting in a risk of salt build-up, leaching losses and nitrate contamination of leafy vegetables. On the other hand, composted manure is thought to be the perfect mean to improve the organic content of the soil in organic crop production. The composting process decreases the amount of these high soluble forms by stabilizing N in larger and more complex organic forms, resembling humic substances (Raviv *et al*., 2005, Sommer and Dahl, 1999, Paré *et al*., 1998).

The latter organic forms of N are unavailable for uptaking until they are transformed into simpler forms by microorganisms (Sommer and Dahl, 1999, Paré *et al*., 1998). A smaller fraction, 5-15%, of the nitrogen in the manure is in a readily available form (NH_4^+, NO_3^-) (Sommer and Dahl, 1999, Paré *et al*., 1998). Nitrogen is the main limiting factor as the other nutrients, as phosphorus (P) and potassium (K) are available in high proportions, 70 to 80% and 80-90% respectively, within the first year (Paré *et al*., 1998). However, after repeated applications of organic manure, an increase in the availability of N and yield has been noticed (Bhardwaj *et al*., 2000, Paré *et al*., 1998).

The release and the availability of nutrients, as well as the nutrient uptake, influence the plant's growth and total yield (Nielsen and Thorup-Kristensen, 2004). Nielsen and Thorup-Kristensen (2004) clearly stated that the distance between meeting the nutrient demands and having excessive nutrient availability is very short and it may result in nutrient leaching losses to the environment or nutrient imbalances or toxicity problems for the plant.

1.3.2 Irrigation

Irrigation is another important factor that affects yield and fruit quality (Singh, 1997). Imbalanced irrigation management practises have a negative impact on the crop yield (Imitiyaz *et al*., 2000a, b, Bose *et al*., 2002). Tomato's yield is very sensitive to irrigation schedules and decreases when the plants are over-watered or there is luck of soil moisture (Imitiyaz *et al*., 2000a, b). Over-watered plants suffer from lack of oxygen that damages their roots and they become susceptible to soil diseases such as *'Phytophtora'* root rot (Bose *et al*., 2002, Singh, 1997). However, if the plants are not watered enough, they become water stressed, resulting in yield losses (Bose *et al*., 2002, Imitiyaz *et al*., 2000a, b, Santamaria *et al*., 2004, Singh, 1997).

Nowadays, most of the irrigation management techniques are based on soil and agroclimatic regimes, but it is still obscure as many factors have to be taken into account; crop's needs in water, microclimate, soil, root-zone moisture status and potential yield, are few of them. Furthermore, quantity, timing and occurrence (Imitiyaz *et al*., 2000a, b), salinity (Olympios *et al*., 2003, Li *et al*., 1999) and way of application (Ahmed *et al*., 2000, Machado *et al*., 2003) of irrigation schedules play a major role in meeting the best quality and quantity (Bose *et al*., 2002, Singh, 1997, Imitiyaz *et al*., 2000a, b, Santamaria *et al*., 2004).

1.3.3 Transplant

In greenhouse production almost all plants are coming from young plant nurseries. These nurseries supply certified plants free of pests and diseases. Other advantage of buying plants from nurseries is, that the producer has the opportunity to select from a range of varieties with many different attributes; varying from colour and taste to resistances to some diseases. The latter is very important to the organic farming as plant protection becomes easier.

Although much research is conducted about the seed treatment or the raising of seedlings and when the right season to transplant is (Bose *et al*., 2002, Singh, 1997, Jones, 1999), there is inadequate research about the right transplant age of the plantlets. The pattern that is followed in Denmark is to transplant the plantlets when the first truss is flowering, while in England transplant is occurred when the third truss has a visible flower (Nick Starkey, personal communication). Pre-flowering is thought to result in vegetative production, while delayed planting in increased yield (Bose *et al*., 2002).

1.3.4 Overall outcome

Controlling the release and the availability of nutrients along with their uptake by the plants is the key for a successful production (Nielsen and Thorup-Kristensen, 2004). The right timing of the transplant and the water supply will affect the growth and the yield.

1.4 Aim of the thesis

As the demand for organic fruits and vegetables, including tomatoes, is increasing, some parameters need to be adjusted, in order to get the highest feasible net returns. The present thesis focuses on two out of the three above-mentioned aspects; the transplant stage and the early irrigation schedule excluding compost, which were presented as being reasons of reduced yield.

The purpose of this selection lies on the fact that the right transplant stage and the early watering schedule are without an experimental or literature feed up, while compost's case has been examined thoroughly and many studies have been carried out (e.g. Raviv *et al.*, 2005, Nielsen and Thorup-Kristensen, 2004, Tüzel *et al.*, 2003).

As the two selected factors, the transplant stage and the early irrigation schedule, have an important role in production, the thesis concentrated on these aspects respectively; firstly, the transplant stages, which are being currently used by the producers, were evaluated in order to determine which is the most efficient. Secondly, four different watering schedules were used in order to examine their effect on the growth and the yield. The purpose of these efforts is ultimately to suggest the plan, which will enhance the net production.

In order to achieve the wanted goal, a whole experimental process was built step by step, applying the different transplant dates and water strategies. Data on plant structures are recorded i.e. plant height, leaf area, stem diameter and dry weight, as well as information about the yield i.e. number of fruits, weight and diameter. All these parameters are evaluated and discussed, along with other observations that were considered interesting.

Our hypothesis was that late transplants would give higher yields, whereas the early ones will lead to higher vegetative growth and low yields. As far as irrigation is concerned, a similar phenomenon is expected to be noticed: large water quantities will result in higher yields but too high water volumes might lead to flower abortion, over-vegetativeness or even death if the plants are suffocated.

2. Materials and Methods

2.1 Experimental set up

2.1.1 Place of experiment

The experiment was conducted at the experimental farm of The Royal Veterinary and Agricultural University (KVL), Taastrup, Denmark (55° 65'N). The experiment was set up at the greenhouse nr.21 (22 m x 12 m x 3 m, length x width x side end). The greenhouse compartment nr.21 was a part of a four-part complex greenhouse, all covered by glass. For heating, four water pipes of 4 cm diameter were used in each side as well as seven additional ones at the height of 3 m. Later on, in the same height, 8 metal bars were placed in order for the plants to be tied up. In the height of 2.5 m and over the plantation, there were 12 (4 lines of 3 lamps each and 2.2 m distance between) high pressure sodium lamps (Master Son-T Pia Agro 400W, Philips, Eindhoven, The Netherlands), providing supplementary lighting. The floor was cemented and the climate control was regulated by a computer running the LCC 1240- Super 1/2/4 ver.52.1 (CWO- VOLMATIC, Denmark) programme.

At the same time, inside the greenhouse there was another experiment running, concerning biological control of common bunt (*Tilletia* sp.) in organic wheat.

2.1.2 Plant material

The plants that were used were 40 days old grafted tomato plantlets (Growgroup Sa, Dutch origin), cv. 'Aromata'. The plants were provided by Markhaven ApS, a commercial enterprise of organic tomatoes and cucumbers in Odense, Denmark. The plants arrived at Markhaven ApS on the 13th of January 2005, having being transported from The Netherlands with seller's special designed trucks. The first pick up took place on the 20th of January 2005. A total number of 25 plants were taken that day. One week later, 75 additional plants were transported to Taastrup. In the meantime, the plants from the first pick up where kept in 16 ^{o}C inside the greenhouse, providing similar conditions to the ones that were still in Odense.

When received and until that the plants were transplanted, all of them were placed on a plastic bench (0.85 m high) and watered up to the point that a thin water film was formed on the bench. The watering was based on how much water was on the bench, not letting it dry completely and before the plants started to thrive.

2.1.3 Growing medium

The growing medium was soil and compost, in a ratio of 1:1 (v/v). Soil originated from the organic field nr. 42 of KVL, at Bakkegaarden, Taastrup. Field nr. 42 was converted for organic purposes; It was planted with lucerne for two of years and then cultivated in a four-year crop rotation, with the following cultivars: pea (2001), barley with grass (2002), clover and grass for grazing (2003) and on 2004 with winter wheat. After the harvest of the year 2004 the field was disk harrowed.

After soil's extraction from the field, it was put indoors on a cemented floor for drying, as it contained a lot of moisture. After drying, the soil was sieved in order to give a homogenised appearance. The soil type was classified as JB6 (Danish classification system), a light clay content soil. After the purchase of the soil, it was put inside the greenhouse for additional drying and sieved once more, through a 2 cm metal net.

The compost was provided by Markhaven ApS. It was transported from Odense, Denmark, to the experimental farm at KVL on the 15th of January 2005. The compost consisted of approximately 75 % cow farmyard manure and approximately 25 % of leaf, branch compost of greenhouse tomato and cucumber. It was prepared around September 1st and before being used, it was remixed.

The mixing procedure of soil and compost took place in the beginning of January, using a soil-mixing machine (Preulec, Royer). After the mixing, a texture analysis and organic matter content was made using the hydrometer method. The results were the following:

Table 2.1: Results from the soil texture analysis and organic matter content.

Coarse sand	35,5%
Clay	5,6%
Silt	18%
Fine sand	40,9%
Organic matter content	17,2%

The blend of soil and compost was placed in 18 *l* pots and depth of 37.5 cm. Pots' diameter were 25 cm. The pots were filled until 5 cm from the top edge and they did not have any drainage holes.

2.1.4 Experimental treatments

2.1.4.1 Transplant treatments

Originally, sixteen treatments were planned; four planting stages and four watering schedules. The four planting stages were determined according to the number of trusses flowering, and these would be: a pre-flowering, first, second and third truss flowering stage. Finally, only the pre-flowering (Group A) and first truss flowering (Group B) was examined as the 40 plants that were meant to be used died due to nutrient burn.

The nutrient burn occurred when organic chicken manure (Binadan 5-2-4, Binadan As, Denmark) was applied to treat plants' nutrient deficiency. Although the application showed relief, a bad estimation in one of the manure quantity in the watering resulted in plants' death.

2.1.4.2 Water treatments (WT)

The watering schedules for the pots were as follows: i) 100 ml, ii) 180 ml, iii) 250 ml and iv) 350 ml of water in each one. The plants that received 100 ml of water were used as indicators when the next watering would occur; when they were starting to wither, all the plants were being watered according to the number of their treatment. The water quantities used, were suggested by Nick Starkey (DEG GreenTeam, Denmark), resembling the quantities in commercial production and adjusted according to plant's needs and pot size.

An overview of the treatments that finally took place can be seen in table 2.2

Table 2.2: Transplant dates and water treatments.

Transplant date	**Water treatment (WT)**	
Group **A** –21 Jan 05 (pre-flowering stage)	1	100 ml
	2	180 ml
	3	250 ml
	4	350 ml
Group **B**- 7 Feb 05 (first truss flowering)	1	100 ml
	2	180 ml
	3	250 ml
	4	350 ml

Watering was done manually. In each application, the quantity was always the same and based on the number of their water treatment. To ensure the exact water quantities, laboratory's glass tubes were used. The water used was taken by the greenhouse tap (table 2.3), which is also used for all the experiments being carried out there. Consequently, the irrigation water did not contain any fertilizers and no fertilizers were used throughout the whole experiment.

Table 2.3 : Water analysis for KVL's tap water (December '04 analysis).

KVL's tap water	
Element	Concentration µg/ l
Ca	72,11
Mg	37,64
Na	85,45
K	6,56
Mn	0,008
Cu	0,008
Zn	1,71
Mo	0,001
B	0,596
Fe	0,707

2.1.5 Transplant

The first transplanting date was on the 21 of January 2005, Group A, the pre-flowering stage. Group B, first truss flowering (having at least 1 open yellow flower) was transplanted 16 days later on the 7th of February 2005. Transplants of Group C and D, 2nd truss and 3rd truss flowering, as already mentioned, never took place, due to the problem that encountered to the plants, when they were kept on the bench.

The plantlets were planted in the centre of the pot and until the half of the soil block that they were in. This technique was implemented by Klaus Sogård, Markhaven ApS, in order to avoid attacks of pathogens that could harm the tomato plant through the base of the stem. After each transplant, 200 ml of water was applied to each plant to achieve contact between the root system and the soil.

Each treatment was replicated five times, giving a total number of 40 plants (1 plant/ pot). The experimental set up was a randomized split- plot design, with planting stage as main plot and irrigation as sub- plots. The plants were grown in 5 rows of 8 plants each and 0.5m distance between them, in a total area of 7 m^2.

Experiment's final appearance can be seen at figure 2.1.

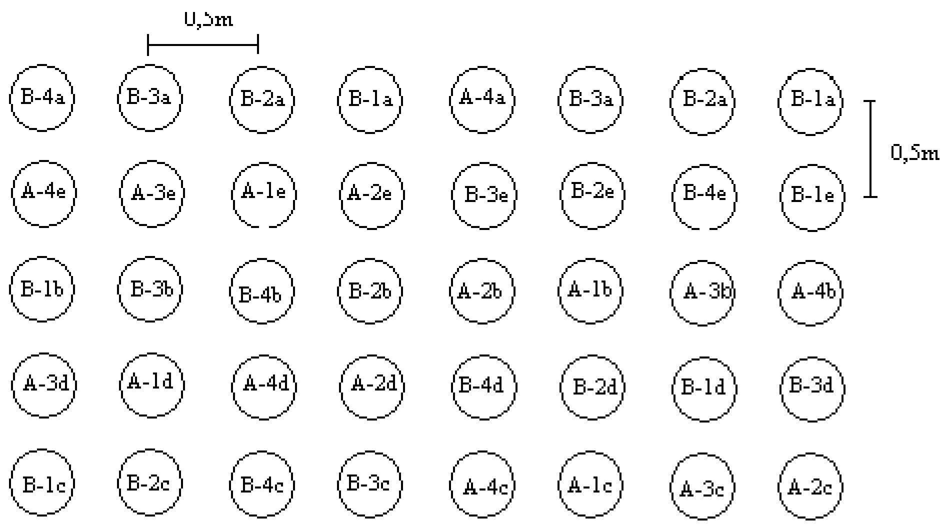


Figure 2.1: The Pots arrangement based on the split- plot design. The capital letter (A or B) indicates the transplant stage, whereas the number (1, 2, 3 or 4) the water treatment. Small letters indicate the replicate.

2.1.6 Climate conditions

The climate conditions (temperature, light, day length) were computer controlled, running the LCC 1240- Super 1/2/4 ver.52.1 (CWO- VOLMATIC, Denmark) programme. There was no relative humidity or CO_2 control.

The temperature set points were adjusted throughout the whole experiment, trying to simulate the conditions that commercial producers have in their greenhouses. In addition, for energy saving purposes, there was a margin of -1 ^{o}C from the temperature set points, before the computer would set off a heating purpose. This had as an affect the heating system not to work all the time trying to keep stable the temperature. Moreover, a margin of +3 (+4, if the sun was high) was implemented in order to take advantage the increased temperature deriving from sun along with the high light intensities, before the greenhouse windows would open for cooling. All these parameters were options of the above-mentioned program and also used by producers.

When the experiment started, the temperature set points were 19 and 16 ^{o}C, day and night, respectively. On the 8th of February, the temperature was adjusted to 22 and 17,5 ^{o}C. On the 22nd of March the temperature was decreased temporarily to 21 and 17 ^{o}C until the 27th of the same month, for a better control of the spider-mite problem. Temperature set points are presented in table 2.4.

Table 2.4: Temperature set points.

Date	Temperature (°C)	
	Day	Night
21 Jan – 7 Feb	19	16
8 Feb – 21 Mar	22	17,5
21 Mar – 26 Mar	21	17
27 Mar – 10 May	22	17,5

Supplementary lighting was used when outside light conditions were less than 7.5 W/ m^2, using greenhouse's sodium lamps (Master Son-T Pia Agro 400W, Philips, Eindhoven, The Netherlands). The same lamps were also used to achieve 16 and 8 hours, day and night, respectively on the winter period. Furthermore, screens were used during spring, for the same purpose. The computer program controlled both procedures.

The relative humidity varied throughout the whole experiment, because it was rather difficult to control it (fig. 2.2). Humidity control attempts were made by wetting the floor, especially in the "hot" and sunny days. Nevertheless, when the air was humid at acceptable levels (>60%), there was an extended accumulation of heat, which had as a result the opening of the windows for cooling and consequently loosing the achieved humidity.

Daily average values can be seen in figure 2.2.

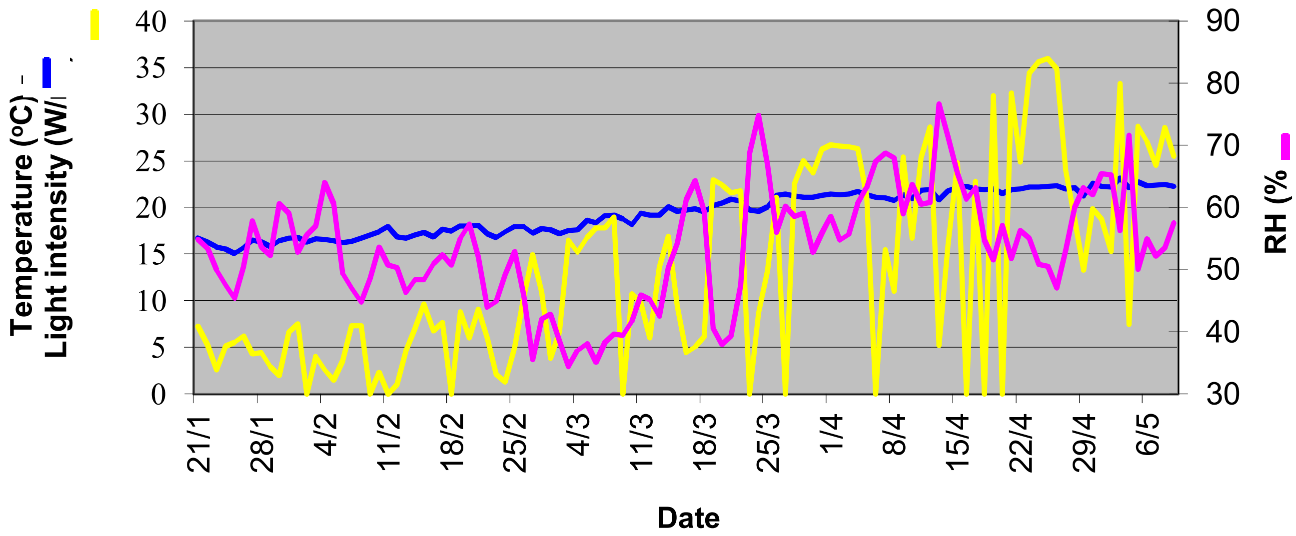


Figure 2.2 : The daily average value of temperature (°C) is presented in blue line (**-**), whereas the outdoor light intensity (W/ m^2) in yellow (**-**). The purple line (**-**) represents the average of the relative humidity (%).

2.1.7 Pest and diseases

The only problem encountered was infection with *Fulvia fulva* (*Cladosporium fulvum*), a fungus that causes cladosporiosis or leaf mold. No special measures were taken apart from removing the infected leaves- as it was not considered a major problem. Symptoms were observed only on the older, basal leaves, close to where the water evaporation from soil occurred (high relative humidity). Furthermore, the climatic conditions (low relative humidity) were not encouraging its development (Agrios, 2005, Blancard, 2000).

Possible presence of pests was observed in the examination of the two pairs (two blue, two yellow) of sticky boards (Borregaard, Bioplant, Denmark), which were placed at the 21st of February. The sticky boards were replaced by 7 pairs on the 21st of March. That day, winged aphids (*Macrosiphum euphorbiae*), spider mites (*Tetranychus urticae*) and thrips (*Thrips tabaci* and/or *Frankliniela occidentalis*) were observed. The pests probably moved from the wheat that was co-cultivated inside the greenhouse; close observation to wheat revealed great and dense populations of aphids, phenomenon that can justify the presence of winged aphids in the tomato plants (Malais and Ravensberg, 2003).

The following day, 22nd of March, immediate actions were taken with the release of natural enemies: *Amblyseius cucumeris*, *Phytoseiulus persimilis*, and *Aphidius colemani* against thrips, spider mites and aphids, respectively. The first two beneficial were purchased by Borregaard Bioplant, Biologisk Planteskyttelse, Denmark, while *A. colemani* from Biobest, biological systems, Belgium. In addition, the greenhouse temperatures was decreased by 1 ^{o}C, in order to achieve more favourable conditions for the beneficials as well as to suppress the development of pests. Furthermore, by lowering the temperature, higher relative humidity was also achieved (figure 2.3).

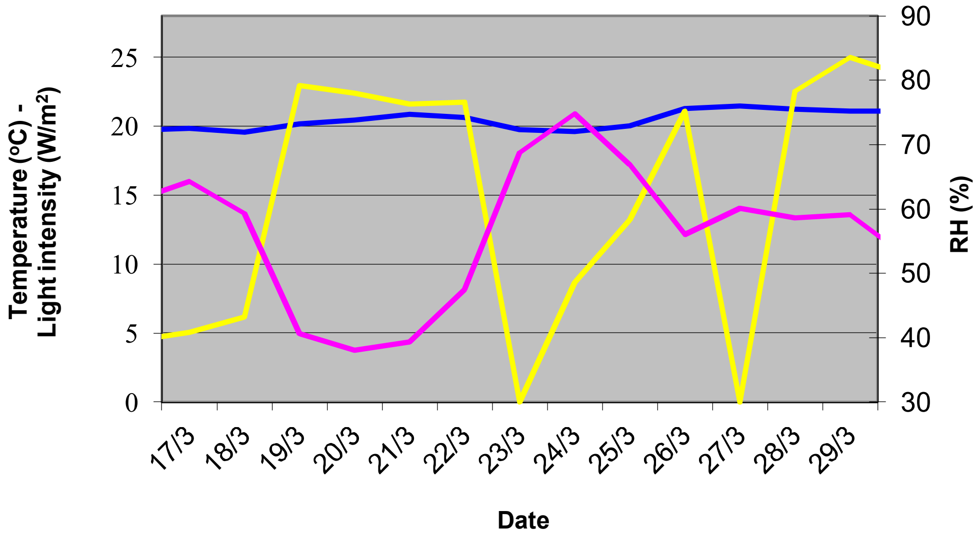


Figure 2.3: Time period (17th to 29th of March) when the temperature was reduced and the higher RH was achieved, for controlling the pests.

The counter measures had excellent results for aphids and thrips, while the ones for spider-mites were not encouraging; they continued to grow, but surprisingly and unjustifiably, only on one plant (B-4a, figure 2.1). On the 31st of March, a new approach was introduced: sulfur. By dusting the plant B-4a with sulfur suppressed the spider-mite population to great extent. Objections arose with the use of sulfur, therefore it was decided to do an additional release (2nd and 3rd of April) of *P. persi*milis which, again, were ineffective. Sulfur came up to the scene again, having good results.

Further releases of beneficials were made on the 22nd of April and 4th of May. In between, the plants were sprayed with an insect soap ('Insektsæbe', Borregaard Bioplant), not approved for biological control of spider-mites. 'Insektsæbe' is an environmental friendly soap based on fatty acids. It is normally used as an herbicide, as its active ingredient, the nonanic acid, can dissolve the cellular walls of the plant cells. Although it had excellent results in the spider mites, it also caused limited defoliation. The people of Borregaard Bioplant are aware of its ability to control pests, therefore, they are in process of getting a license for use in organic farming (internet –http://www.bioplant.dk/Nyttedyrdk/produkter.php?produkt_id=16).

2.1.8 Cultural practices

It was decided to follow the one-stem cultivation technique. For that reason, the plants were trained vertically and topped at the height of 3 m. Periodic operations of binding and lateral stem and basal leaf removal were carried out.

To enhance and ensure pollination, the wires that the plants were tightened up were vibrated daily by hand during the first 2 weeks, causing vibration to the whole plant. Later on, each truss was individually vibrated manually 6 times per week, reducing the risk of unpollinated flowers.

2.2 Measurements

On the early stages of each plant's development, measurements were taken concerning leaf area (LA) and height of the plants. The leaf area measurements were taken every 13 days using a non-destructive method. Later on, it was impossible to take the LA measurement, because of the beneficial insects' presence on the leaves, which would be damaged, if the grid was placed on the leaves. The whole process and its principle are revealed in the following paragraph.

The height of the plants was measured throughout the whole experimental process, using a ruler and starting from the base of the stem until the top.

Fruits were harvested by hand and only from the first four trusses (table 2.5). The number, the weight and the maximum diameter of fruits were recorded, for each fruit and plant individually. Abnormal shape (ABN) or incidence of blossom end rot (BER) was also taken down. The fruits that were classified as ABN had an irregular, non-commercial shape. The fruits with BER symptoms, where they were met, were always visible and easy to distinct, (at least 1 cm diameter). The total soluble solids were also estimated with the aid of a table refractometer.

Table 2.5: Dates of fruit gathering for each group.

Transplant Group	Group A	Group B
Harvest date	22/ 4	20/ 4
	25/ 4	24/ 4
	28/ 4	29/ 4
	2/ 5	3/ 5
	4/ 5	7/ 5
	10/5	10/ 5

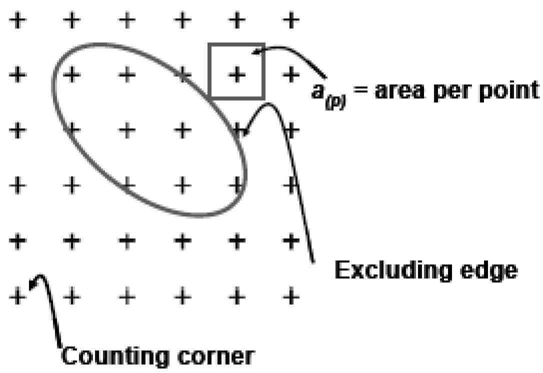
When the experiment was terminated, the dry weight of the plants, as well as the number of clusters, the height and stem diameter (between the 3 and the 4^{th} cluster) measurements were recorded.

2.2.1 Leaf area determination

Due to the small number of plants, a non destructive method of LA estimation was decided to be followed. In this way it was possible to use the samples throughout the whole experiment.

The determination of the leaf area method was based on stereology, a method for collecting quantitative information about three-dimensional objects provided by observations on two-dimensional sections, as described by Gundersen *et al.* (1988). The main idea behind stereology is not to reconstruct an object, but to obtain representation of the object, first by sampling using efficient techniques and then analyzing the data using simple geometric techniques as Sciortino (2005) states. Stereology application in agriculture is used in the estimation of the total 3D root length and the estimation of the total number of flowers on trees. (Sciortino, 2005).

In the present thesis, the estimation of the desired leaf area was based on counting the points that 'hit' the grid. Grids are transparent films with different point densities (area per point $\alpha_{(p)}$). For practical reasons, as points were used crosses and choosing a "counting point" as presented in picture 2.3. The grid was randomly placed on the desired surface and the number of points was counted. Then, the leaf area estimation is given by the following formula:



Picture 2.3 : Points hitting the desired surface (eclipse) are counted in order to estimate the desired area. (taken from Sciortino M., 2005)

$$E = \Sigma p \cdot \alpha_{(p)}$$

where:

- E is the estimated area (cm^2)
- Σp is the total number of counted points
- $\alpha_{(p)}$ is the area per point of the grid (cm^2)

Sampling all leaves of all plants would be impractical and time consuming. Therefore, the fractionator, a simple sampling scheme of stereology, was also implemented. In our case, instead of counting all the points in all the leaves, a fraction of them was decided to be counted. The fractionator's principle consists of several sampling stages with Systematic Uniform Random Sampling with known and predetermined probability, all described by Sciortiono (2005).

In summary, the whole leaf area estimation was carried out with the following parameters: The size of the grid was 5,945 cm^2. The sampling period was to count all points, one in every three compound leaves, giving a sampling fraction of f = 1/3. As the plants' leaf area increased, the counting procedure became more time consuming. Therefore, the grid size increased to 9,57 cm^2 and an additional sampling factor was introduced, counting the points only to one half of the compound leaf, giving a total fraction of f =1/6.

The sampling of the plants was always beginning from the bottom to the top using a random start number (*r*= 1, 2 or 3). The next random start, for the next plant was given by the difference between the sampling period and the last leaves which were not sampled at the top of the plant.

So the final equisition to estimate the total leaf area, including the parameter fractionator, was:

$$E = 1/f \cdot \Sigma p \cdot \alpha_{(p)}$$

2.2.2 Estimation of total soluble solids in fruits

Three to five tomatoes (depending on the size), representing a good sample (based on the appearance; typical size and colour), of each treatment were cut in small pieces and put in a blender mixer, giving a liquid form. The liquid forms were left for 24h to rest, in order to have two visible phases, because samples should not contain solid substances. Using disposable pipettes, samples were taken from the low viscosity phase and put in the prism of a refractometer (RFM 90, Bellingham and Starkey limited) where, they were left up to 30 seconds to allow temperature stabilization between the prism and sample.

The refractometer took multiple (5 times) readings and was given a mean value. Before the next sample was put for reading, the prism and the press were cleaned carefully with water.

2.2.3 Statistical analysis

For analyzind the experinmental data, in order to see any statistical differences between the treatments the analysis of variance (ANOVA) and Tukey's Studentized Range (HSD) test (α= 0,05) was used. Analyses of variance were carried out on the data of the transplanting date and the watering schedule concerning the plants' growth and production. Furthermore, to check for significant differences between transplanting date and water treatments in plant and fruit characteristics, Tukey's Studentized Range (HSD) test (α= 0,05) was carried out on the mean responses.

Fruits' total soluble solids were also examined to determine statistical significance, performing the same procedure (Tukey's test, α= 0,05) between means.

All analyses were performed with the statistical software package SAS /STAT, ver 9.0 (SAS

3. Results

3.1 Plant characteristics

Our initial hypothesis was that the earlier transplanted plants would have higher vegetative growth and lower yield, whereas the late transplant would have higher net returns. The vegetative growth would be monitored by observing plants' characteristics such as the leaf area, the height, the number of trusses and the dry weight. In addition, the changes that occurred between the watering treatments and transplanting dates, throughout the whole growing period, were observed, recorded and consequently supported or refuted by the statistical analysis

3.1.1 Leaf area (LA) estimation

The original plan of taking leaf area measurements was every 13 days. Unfortunately, that plan could not be met, due to the natural enemies' release. Nevertheless, for a certain period of time, measurements were applied normally. Consequently, on the 26th of January, on the 8th and 25th of February and on the 10th of March, measurements were taken for Group A, whereas concerning Group B, the delayed transplanted plants, only two LA estimations were possible; on the 16th of February and 3rd of March. All measurements were recorded and presented in Figures 3.1 and 3.2.

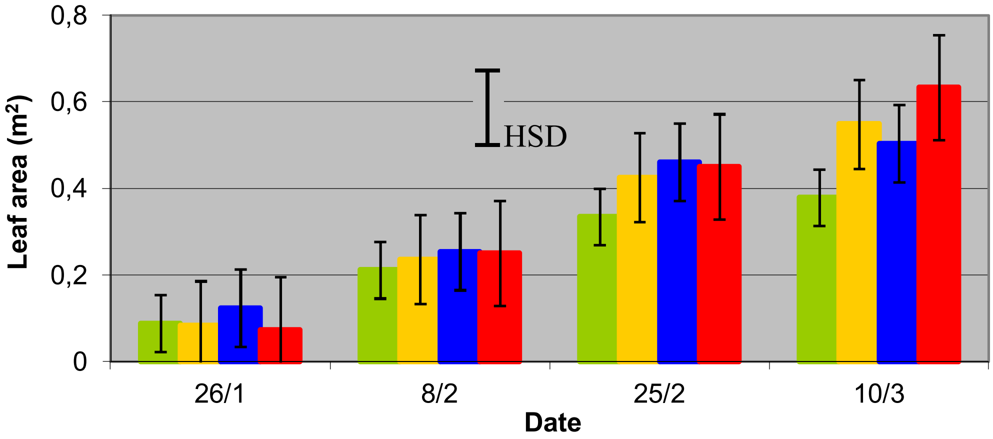


Figure 3.1 : Estimated Leaf Area (m^2) of Group A, the pre-flowered transplanted plants. Green, golden, blue and red bar present water treatments 1,2,3 and 4, respectively. Statistical analysis (HSD test, alpha 0,05) did not show any significant differences (Minimum significant difference 0,184)

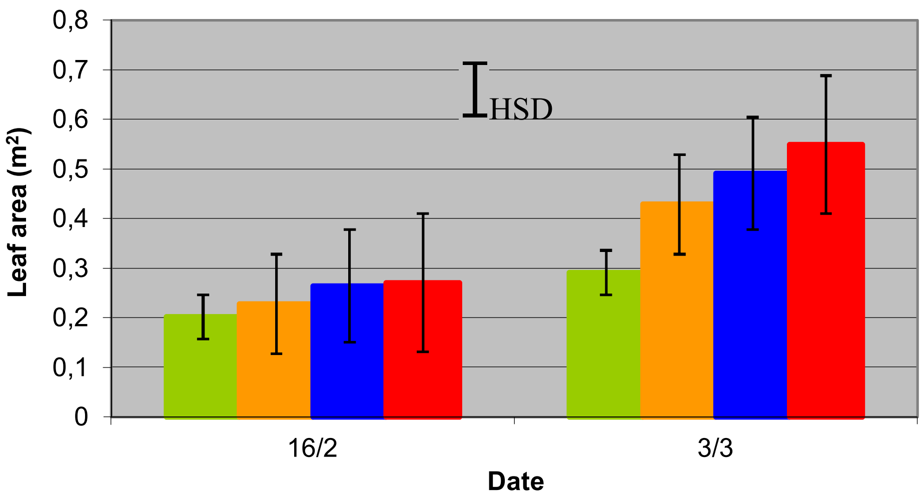


Figure 3.2: Estimated Leaf Area (m^2) of Group B, the plants that had the first truss flowered when they were transplanted. Green, golden, blue and red bar present water treatments 1,2,3 and 4, respectively. Statistical analysis (HSD test, alpha 0,05) showed only minor significant differences (Minimum significant difference 0,117).

Although, a first observation of the above figures may lead us to assume that larger quantities of water resulted in higher LA, the statistical analysis confirmed our assumption; larger LA measurements were taken from the plants that were watered with the 350 ml (WT4), but the differences were not significant (table 3.1). Unfortunately, due to the fact that the plants' LA measurements were taken on different dates, a comparison between the two transplanting dates would be out of question.

Table 3.1: Average LA on the last measurements of both Groups. Means followed by the same letter are not significantly different. (Minimum significant differences; Group A: 0,184 and Group B: 0,117)

	Water treatment	LA (m^2)		Water treatment	LA (m^2)
Group A	1	$0{,}379^{b}$	Group B	1	$0{,}292^{c}$
	2	$0{,}549^{ba}$		2	$0{,}429^{b}$
	3	$0{,}504^{ba}$		3	$0{,}491^{ba}$
	4	$0{,}634^{a}$		4	$0{,}549^{a}$

Morever, a minor disorder was noticed in the last measurement (10/3) of Group A; number 3 treatment (table 3.1) had a reduced LA (0,504 m^2) compared to treatment number 2 (0,549 m^2). Most probably, this happened because one's plant (A-3b, picture 2.1) apex shot was pruned by mistake and a secondary stem was left as substitute.

3.1.2 Height

Along with the LA, height would give us a first view of the vegetativeness of plants; tall and leafy plants indicate higher vegetative growth. The height was measured throughout the whole experimental process. The values that were recorded, are presented in figures 3.3 and 3.4.

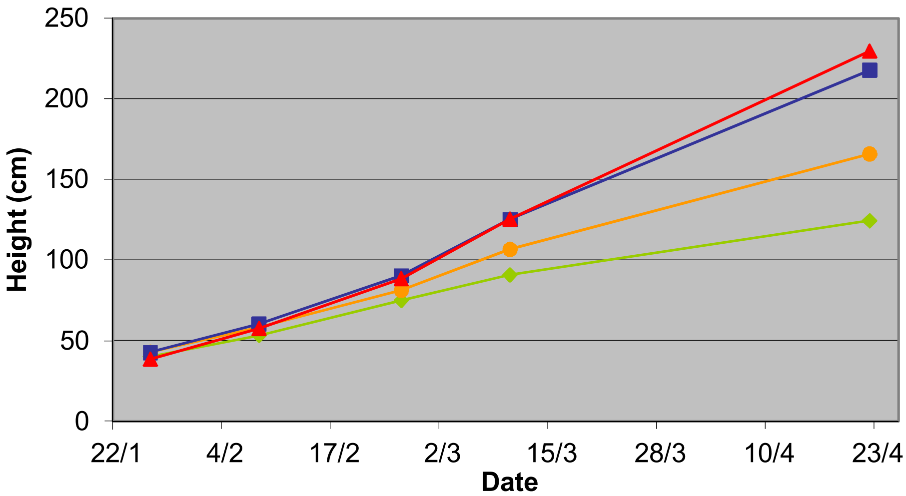


Figure 3.3 : Average height of each treatment of Group A. Green line presents WT 1 (-◆-) , golden WT 2 (-●-) and blue WT 3 (-■-). With red colour is WT 4 (-▲-).

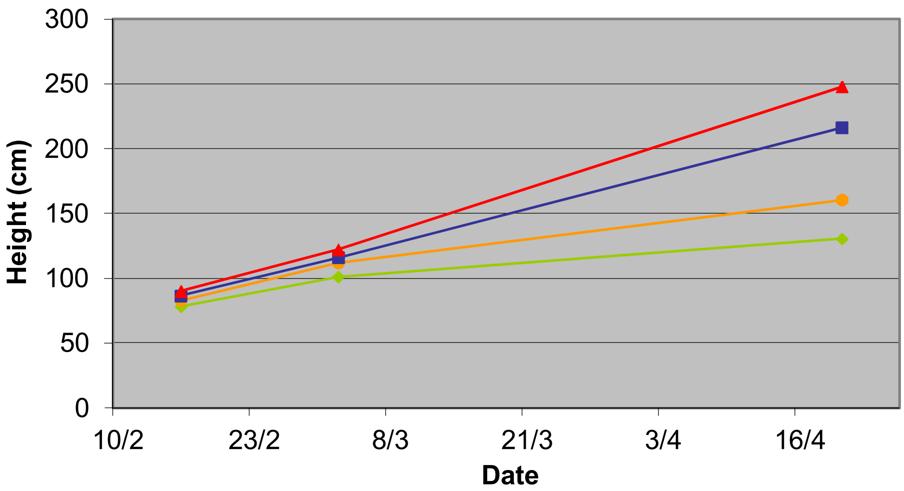


Figure 3.4 : Average height of each treatment of Group B. Green line presents WT 1 (-◆-), golden WT 2 (-●-) and blue WT 3 (-■-). With red colour is WT 4 (-▲-).

Observed results are similar to the ones of LA estimation; larger water quantities lead to taller plants. In contrast with the LA estimation, the final height was measured almost on the same date (20/4 and 21/4) and therefore, a comparison between them is acceptable. While the mean values are presented in table 3.2, a HSD test (alpha 0,05) was conducted and the results showed that there were significant differences between the water treatments; higher plants (229,6 and 247,8 cm)were the individuals that were watered with larger amounts of water (350 ml), whereas the plants of water treatment 1 were significantly the shortest ones (124,4 and 130,5 cm). In addition, the HSD test did not reveal any significant differences between the transplant strategies (data not shown).

Table 3.2: Average final plant heights. Means followed by the same letter are not significantly different. (Minimum significant difference 18,3 cm.)

	Water treatment	Final height (cm)		Water treatment	Final height (cm)
Group A	1	$124,4^{d}$	Group B	1	$130,5^{d}$
	2	$165,8^{c}$		2	$160,5^{c}$
	3	$217,8^{b}$		3	$216,3^{b}$
	4	$229,6^{a}$		4	$247,8^{a}$

3.1.3 Final number of trusses

The number of trusses was expected to be according to plant's height, as long as the climate conditions were the same. One fruit truss every three leaf knots was what was anticipated, and therefore, taller plants were expected to have more trusses. The purpose of counting the number of trusses was not to compare the vegetative growth but to observe if any of the treatments did not promote their development.

Having that into consideration, the day that the plants were eradicated (10^{th} May), the number of trusses (of at least 1 cm length) was counted. The mean final number of trusses is shown in table 3.3.

Table 3.3: Average final number of trusses per water treatment. Means followed by the same letter are not significantly different (Minimum significant difference 1,02)

	Water treatment	Number of trusses		Water treatment	Number of trusses
Group A	1	$6{,}4^{c}$	Group B	1	6^{c}
	2	$8{,}2^{b}$		2	$7{,}4^{b}$
	3	$9{,}2^{a}$		3	9^{a}
	4	$10{,}2^{a}$		4	10^{a}

Differences were obverved between the water treatments; greater truss number (10,2 and 10) was in correlation with higher water volumes (350 ml). Consequently, WT 4 had the highest number of trusses, followed by the ones of WT 3 (9,2 and 9) with no significant differences. No significant difference was also noticed between the means of the two transplant stages.

3.1.4 Plant dry weight

Finally, when the experiment was terminated, the dry weight of the plants was also measured. The dry weight data would reveal how succulent the plants were. Moreover, the leaf (Ldw) and stem dry weight (Sdw) were measured separately. The purpose of the action was dual; firstly, to observe if there was any correlation between the LA estimation and leaves' dry weight and secondly, to seek any correlation between the stem diameter and the stem's dry weight. The average values can be seen at figure 3.5

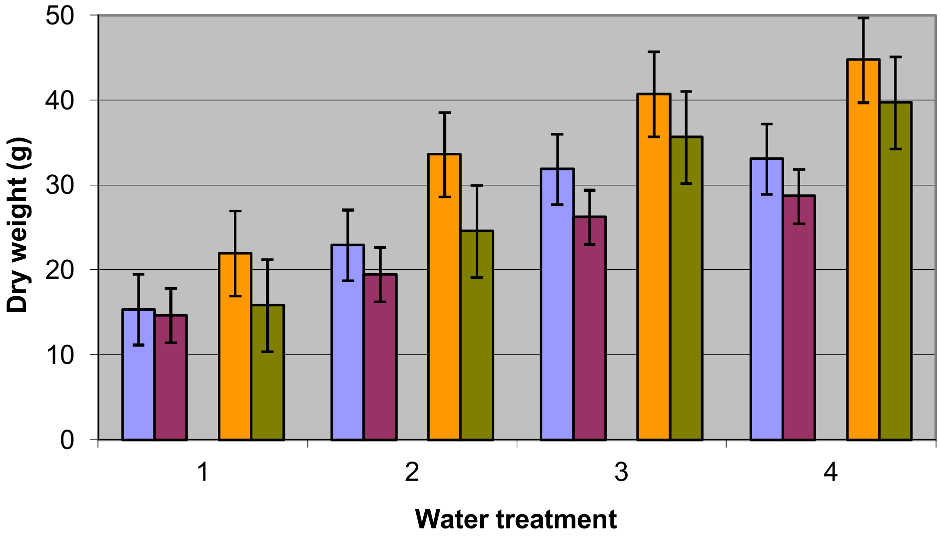


Figure 3.5 : Plants' average stem and leaf dry weights. Blue and purple bar represent stem dry weight of Group A and B, respectively. Orange bar shows leaf dry weight of Group A while the green bar the one of Group B.

As it may be noticed, the larger irrigation quantities resulted in increased dry weights. Tukey's Studentized Range Test (HSD, p=0,05) confirmed our suggestion; it revealed significant differences not only between the water treatments (table 3.4) but, also between the two transplant stages (table 3.5). The pre-flowering transplant (Group A) had significantly higher mean values than transplant Group B, whose transplanted plants had their first truss flowered.

Table 3.4: Plants' average stem (Sdw) and leaf (Ldw)dry weights (g). Means followed by the same letter are not significantly different (Minimum significant differences; Sdw: 1,85 and Ldw: 3,59)

	Water treatment	Sdw	Ldw		Water treatment	Sdw	Ldw
Group A	1	15,4^{d}	22^{d}	Group B	1	14,7^{d}	15,8^{d}
	2	22,9^{c}	33,6^{c}		2	19,5^{c}	24,6^{c}
	3	31,9^{b}	40,7^{b}		3	26,2^{b}	35,6^{b}
	4	33,1^{a}	44,8^{a}		4	28,7^{a}	39,7^{a}

Table 3.5: Groups' average stem (Sdw) and leaf (Ldw)dry weights (g). Means followed by the same letter are not significantly different (Minimum significant differences; Sdw: 0,98 and Ldw: 1,9)

	Sdw	Ldw
Group A	25,8^{a}	35,3^{a}
Group B	22,3^{b}	28,9^{b}

3.2 Fruit characteristics

Our main objective was to achieve the best production. By the term "best", not only quantity but also the quality is meant. Therefore, apart from the total yield in weight and numbers, other parameters were also taken into consideration; the size of fruits, the incidence of non-commercial shape and the amount of soluble solids, that affect the taste. Although there were no in-depth tests for the fruits such as texture, colour or aroma, thesis focused mainly on the above-mentioned, outer characteristics and the amount of soluble solids, without defining the different components.

3.2.1 Yield

The total yield for every watering schedule of both transplant stages, along with their characteristics is shown in tables 3.6 and 3.7.

Table 3.6: Fruit yield characteristics of group A, the pre-flowering transplant stage. The second column indicates the total number of fruits collected. The third and forth column reveal the total (Kg) and per fruit (g) weight of the fruits, respectively. Their diameter (mm) is shown at the fifth column. The total number of abnormal (ABN) fruits and those with symptoms of blossom end rot (BER) are shown in the penultimate and last column, respectively. Values are followed by the standard deviation response in brackets.

Group A						
Water treatment	Total fruits	Total weight (kg)	Aver. Weight (g)	Aver. Diameter (mm)	ABN fruits	BER Fruits
1	61^b (1,5)	$1,3^d$ (0,04)	$21,3^d$ (1,9)	$36,4^d$ (1,8)	10^a (1,9)	2^a (0,5)
2	72^b (2,3)	$2,1^c$ (0,04)	$28,8^c$ (1,9)	$40,0^c$ (1,6)	4^a (1,3)	7^a (1,5)
3	92^a (3,6)	$3,9^b$ (0,08)	$41,9^b$ (5,1)	$46,2^b$ (2,6)	9^a (2,9)	8^a (1,5)
4	96^a (2,4)	$4,9^a$ (0,13)	$50,8^a$ (6,8)	$50,7^a$ (2,1)	9^a (1,6)	6^a (0,8)

Table 3.7: Fruit yield characteristics of group B, the transplant stage where the first truss had flowered. The second column indicates the total number of fruits collected. The third and forth column reveal the total (Kg) and per fruit (g) weight of the fruits, respectively. Their diameter (mm) is shown at the fifth column. The total number of abnormal (ABN) fruits and those with symptoms of blossom end rot (BER) are shown in the penultimate and last column, respectively. Values are followed by the standard deviation response in brackets.

Group B						
Water treatment	Total fruits	Total weight (kg)	Aver. Weight (g)	Aver. Diameter (mm)	ABN fruits	BER fruits
1	71^{b} (2,7)	$1,6^{d}$ (0,04)	$22,5^{d}$ (3,5)	$37,1^{d}$ (2,3)	3^{a} (1,3)	1^{a} (0,4)
2	91^{b} (1,3)	$2,6^{c}$ (0,03)	$28,7^{c}$ (2,8)	$39,7^{c}$ (1,4)	4^{a} (1,3)	1^{a} (0,4)
3	106^{a} (4,7)	$3,9^{b}$ (0,16)	$37,0^{b}$ (4,3)	$43,5^{b}$ (2,0)	1^{a} (0,4)	1^{a} (0,4)
4	124^{a} (2,5)	$5,2^{a}$ (0,04)	$42,0^{a}$ (5,1)	$45,3^{a}$ (2,4)	3^{a} (0,5)	8^{a} (2,5)

The statistical analysis showed that there were significant differences in the attributes of the fruits, related to both aspects of date and water treatment. Their number, weight and diameter were significantly increased along with the increase of the water volumes, whereas restricted amounts of water resulted in lower production. Characteristically, the total weight of WT 4 is approximately 3,7 times higher than the one of WT 1 in group A, while in group B regarding the same comparison the results were 3,2 times higher.

The incidence of fruits with BER was not significantly different either from date's or water treatments' aspect. Contrary to BER fruits, the statistical analysis of the ABN fruits indicated difference between the two planting stages (Group A and B), although differences were not observed in the water treatments. Group A was the group which revealed higher incidence of fruits with abnormal shape.

3.2.2 Total soluble solids

With the assistance of the table refractometer, the total soluble solids were measured. The total amount of solids was measured, as they affect the taste of the fruits. The results can be seen at figure 3.6.

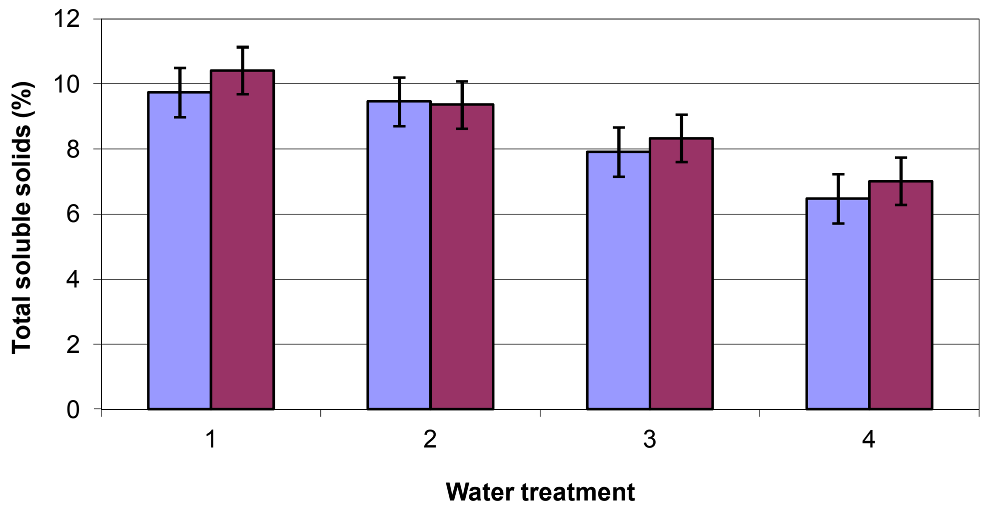


Figure 3.6 : Total soluble solids of tomato fruits according to their water treatment. The blue bars indicate the concentration of Group A, the pre-flowering transplant stage, while the purple one, the concentration of soluble solids of Group B, the transplant stage where the first truss had flowered.

What is noticed and confirmed by the HSD test (table 3.7), is that higher (9,7 and 10,4) concentrations of soluble solids are met to fruits that were watered with small water volumes. WT 4 had the lowest concentration of soluble solids among all water treatments in both transplanting stages (6,5 and 7). No significant difference was found between the two transplanting groups.

Table 3.8: Fruits' average total soluble solids (%). Means followed by the same letter are not significantly different (Minimum significant differences; Group A: 0,7 and Group B: 0,9)

	Water treatment	Total soluble solids		Water treatment	Total soluble solids
Group A	1	9,7[a]	Group B	1	10,4[a]
	2	9,5[a]		2	9,4[b]
	3	7,9[b]		3	8,3[c]
	4	6,5[c]		4	7[d]

3.2.2 Plant dry weight relationship with fruit weight

Finally, having the total (leaf + stem) dry weight of the plants along with the total weight of harvested fruits, an effort was made in order to investigate, if there is a correlation between the two characteristics. The following figure (fig. 3.7) shows the dry weights of plants and their net return responses.

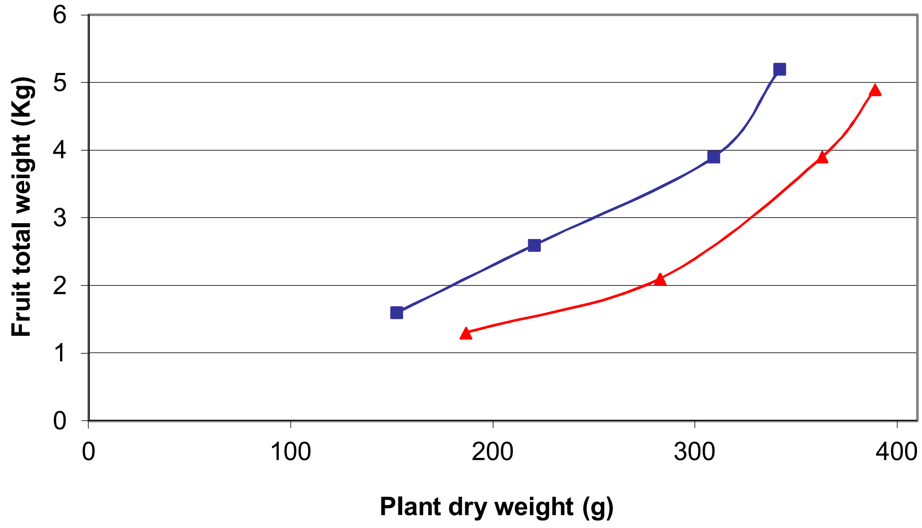


Figure 3.7 : Plant dry weight in correlation with the fruit weight responses. The red colour line (▲) presents Group A, while with the blue line (■) is Group B.

Group A (red line) trend is placed to a right and lower position, comparatively with the trend of Group B (blue line). This characteristic indicates that the plants of the observed group had higher dry weight and lower fruit production, confirming our initial hypothesis.

4. Discussion

The major aim of the present thesis was to support or refute the following assumption; late transplanting of tomatoes lead to higher yields, whereas, the early one to higher vegetative growth. Moreover, this study tried to evaluate the different irrigation schedules, so as ultimately to suggest the plan that will have the highest net returns.

The thesis' results demonstrate that the above assumption was correct; the plants, which had their first truss flowered had more increased yield than those that were transplanted immediately. The total weight and fruit number were higher, contrariwise to the fruit's diameter along with their incidence of non-commercial shape. However, the fruits of the experiment turn out to be smaller than those the market demands, which was attributed either to the fact that there was no flower and fruit load reduction, or to a possible increased salinity level on the soil. Nevertheless, due to a feeding problem that encountered on the plants, which were meant to become the much later transplants (second and third truss flowered), no information became available concerning their possible yields.

Moreover, although the set up experiment would demonstrate the differences in the vegetative growth between the two transplant stages, there was no strong evidence that would help to draw clear conclusions; the non-destructive LA estimation procedure was not consistent throughout the whole experiment, due to the presence of the beneficials on the leaves. Furthermore, the height, trusses and leaf knots measurements did not show any significant differences. Therefore, the only evidence that could be used and evaluated was the dry weight of the plants, which showed that later transplanted plants had reduced dry weights.

Nevertheless, as far as the watering schedules are concerned, the larger volumes resulted in a higher fruit set, along with a vegetative production in both transplant stages, where the lower water quantities in a smaller production, consisting of shorter and more fragile plants. Moreover, the latter plants had increased concentrations of total soluble solids in their fruits.

4.1 Vegetative growth of plants

It has been suggested that plants' growth rate higher, if the plants to do not subject to water-stress conditions (Ahmed *et al.*, 2000). Unfortunately, the LA estimation results did not draw any clear conclusions; on one hand, significant differences were found between the water treatments (table 3.1) but, on the other, no comparison would be advisable on the two transplant dates as data were recorded on different dates. The fact that the observed differences were not so distinct, may be attributed to the fact that there were not many measurements taken. This was not feasible as the beneficials were on the leaves and the grid's use prerequisite is to make contact with the leaves. Torrecillas *et al.* (1995) suggested that after rewatering the stressed tomato plants, the vegetative growth came up to normal levels, but at the late stages of development the recovery was not complete. Therefore, it may be assumed that greater differences, if any, would be encountered later on.

By contrast, significant differences were found between the water treatments, as far as final height (table 3.2) and number of trusses (table 3.3) is concerned. The optimal vegetative development is achieved only when plants are able to cover constantly their needs (Torrecillas *et al.*, 1995). The WT 4 with the 350ml per application was the one closer to it. Plants' height was increased along with the water quantity applied (table 3.2), together with the number of trusses (table 3.3) and number of leaf knots (data not shown). The earlier growth coming from higher plants and consequently giving increased number of trusses, are signs of accelerated maturity for harvest (Ahmed *et al.*, 2000).

However, height is not the only indicator of accelerated growth; biomass is also important (Ahmed *et al.*, 2000). The plants that had received the largest amount of water (WT 4) had a higher dry weight at the final harvest (table 3.4). Significant differences were found not only between the water treatments, but also between the transplant stages; Group A plants had increased dry weights than those of Group B (table 3.5). Ahmed *et al.* (2000) suggests that plants have greater growth, because of the improved plant nutrition, due to the fact that they have extended retention in the growth medium. Furthermore, the plants of WT 4 were stronger (not easy to break) and easier to manipulate than those of the other treatments; a single sudden move could damage a truss or a whole leaf.

4.2 Fruit production

4.2.1. Yield

The results of this study on one hand showed that the WT 4 of both planting stages gave the highest yield numbers regarding the number of fruits, the weight and the diameter, whereas there was no significant difference in the number of ABN or BER fruits (tables 3.6 and 3.7). On the other hand, they showed that the reduced water application resulted in higher quantities of total soluble solids in fruits (table 3.8). These soluble solids, consisting of sugars, mainly glucose and fructose, and organic acids, mostly citric and malic acids, are mainly responsible for the overall flavor of tomato fruits (Kirda *et al*., 2004).

The increased weight and number of fruits in the WT 4 was expected, as the fruit production in tomato plants is affected by expansive growth and sugar accumulation (Kitano *et al*., 1996). The fruit expansive growth depends on water balance among the phloem sap flux, xylem sap flux and transpiration flux in the fruit, as described by Kitano *et al.* (1996). These relationships are considered to be affected by root water condition, such as water availability and salinity (Kitano *et al*., 1996).

The results are similar to the findings by Ho (1996), who showed that the tomato fruit size is inversely related to soluble solids. Consistent with findings by Kirda *et al.* (2004), the reduced applied irrigation water of the present study promoted significant higher soluble solid content (table 3.8) at the expense of reduced net return and smaller sized tomato fruits (tables 3.6 and 3.7). The results show that the 'enhanced' fruit quality was achieved at a cost of up to a 70% reduction in the yields.

Furthermore, by comparing the data between the two transplanting stages, it may be noted that although the number of fruits and total weight of Group B was slightly increased, the average weight and diameter did not follow the same pattern. In Group B, these numbers were lower than the ones of Group A. The phenomenon is attributed to the larger number of fruits that were produced by these plants and to the fact that there was no fruit load reduction on the trusses. Some trusses had up to 10 fruits on a single truss (data not shown) whereas, the producers restrict the fruit load to maximum 6 per truss (Klaus Sogård, Markhaven Aps). Bertin (2005) stated that reduction of plant fruit load, promoted the fruit growth rate and final fruit size. The plants of the latter transplanting, Group B, had earlier and higher rates of fruit set (data not shown).

Moreover, the overall comparison of the transplanting stages, regarding both the vegetable production and the net return, confirmed our initial hypothesis; the earlier transplant had increased vegetative growth and lower yield. Figure 3.7 supports the findings, as the trend is placed to a lower-right position comparatively with the one of the later transplant

4.2.2 Quality

Despite the fact that WT 4 had increased individual fruit weight and fruit diameter in comparison with the other water treatments, neither the size nor the weight is close to the standards of the market. The Danish market demands fruits around 80-90 g (Klaus Sogård, Markhaven Aps), whereas study's fruits are much smaller. Although at the planning of the experiment all the factors were carefully and unbiased selected, no reason of the problem can be given with certainty and only some assumptions can be made:

Firstly, it is the way of pollination. Although the majority of the growers uses bumble bees to enhance pollination (Klaus Sogård, Markhaven Aps), the pollination method that was used to the present study was vibration of trusses by hand. This method can be said that is equivalent to the use of an electric vibrating band. Pressman *et al.* (1999) stated that there were no significant differences between the use of bumble bees and of an electric vibrating band regarding fruit set or yield, when the vibration was taking place frequently (daily). In the present study, the vibration process was almost daily, 6 times per week minimizing the risk of reduced yield.

Another potential source of the reduced size of the fruits can be possibly an increased salinity level on the soil. Van Ieperen's (1996) work had shown a significant reduction in the average fruit weight, but not in the fruit number, even at low levels of salinity. Olympios *et al.* (2003) stated that the salinity effects in yield are observed only as a restriction in the fruit size, during the first 4 weeks of harvest and later on, as well as to a decrease in the number of harvested fruits. In the present study, unfortunately, no measurements were taken considering the EC of the irrigation water or of the soil extract in the root region. Therefore, our hypothesis of increased salinity cannot be fully supported, although the increased total soluble solids might be an evidence of it. Li *et al.* (1999), Santamaria *et al.* (2004) and Olympios *et al.* (2003) reported that the increased salinity improves the fruit quality in terms of flavour, probably attributed to the higher concentration of soluble solids. In present study's findings, the minimum level of the soluble solids is 6.5%, for WT 4, Group A (table 3.8), where a portion of 4.5-7% is thought to be appreciable (Ofosu-Anim *et al.*, 2000). On the other hand, this might not be much of clear evidence, as the increased soluble solids may be attributed to the water stress that the plants were exposed to (Santamaria *et al.*, 2004, Torrecillas *et al.*, 1995).

5. Conclusion

The main goal of the thesis from the beginning was focused on finding the pattern, which would enable the organic tomato producers to increase their net returns. The most common practice for organic tomato's cultivation, that is used so far, is mostly based on assumption and knowledge inherited from past experience. However, the consumer's needs have changed and the trend is oriented towards more is organically grown products and they are even willing to pay higher prices for their purchase.

The initial hypothesis of the experiment was that the later transplant along with a specific water quantity for each tomato plant would fulfill our purpose. The thesis outcome did not fail our expectation; the late transplant of tomato had the highest yield and the high water potential led to an increased weight and number of fruit production, resulting in higher net returns within the same transplant. Consequently, this means that the late transplant, along with ample watering may be the pattern that should be suggested to the producers, so as to enable them to receive higher fruit production. The ultimate goal to achieve the high net returns was reached and the thesis' results may be handful for the commercial organic tomato production.

Moreover, another incident should be taken into consideration; the concentration of the soluble solids of the fruits decreased as the watering quantity was increased and this is an element that should not be ignored, because soluble solids are responsible for the flavour of tomato. High concentration of them, makes tomatoes more 'tasteful'. According to a research conducted in Germany (Dabbert *et al.*, 2004), consumers' top motives for selecting a food product were freshness and taste, moreover, they were also willing to pay extra amount for the products that with these attributes. This notion rises another issue; is it possible the reduced production (quantity) along with the along with the reduced inputs but a better taste, of the organic tomato, to be the perfect profit balance for the producers, as the final earning will be equivalent or even better? This query sounds interesting and it may be a possible suggestion for a future research.

All these results are an initial effort and based on the pattern, which is followed by Danish producers. However, further research needs to be carried out both on even later transplant stages, as well as different watering schedules. Moreover, taking into account that there is still lack of information concerning the 2nd and 3rd truss flowering. it is obvious that further research is required. A new longer-term set up, with the present thesis as foundation, may lead to new findings.

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Appendixes

Appendix I: Plant protection

Although plant protection was not one of our primary objectives, an interesting issue came up that could not be ignored;

Mainly, the pests and more precisely, the spider mite problem was the most difficult situation that was met. There are two possible explanations that can justify the pest problem and counter-measures that could have been taken, in order to alleviate the situation;

Firstly, before the 21st of March, date that the pests were observed in the cultivation, there was a short period of high light intensity, resulting in higher temperatures and extremely low humidity (figure 2.3). These conditions were extremely favourable for development, to all the encountered pests and especially to the spider mites (Malais and Ravensberg, 2003). Therefore, their population growth was rapid. By lowering the day temperature by 1 ^{o}C, the RH raised (>65-70%), turning the tide in favour of the beneficial that were used. *A. cucumeris* a predatory mite that was used against thrips has a critical level of 65% RH, whereas *P. persimilis*, another predatory mite against spider-mite, develops better at lower temperatures (Malais and Ravensberg, 2003). This is probably also the reason that the following releases had such a restricted effect. *A. colemani*, the parasitic wasp that was used against aphid did not have any 'special' requirements and the control of aphids was rather easy.

The second reason that could deter the pest establishment was the co-cultivation. Rather arbitrarily, the assumption that wheat and the tomato do not have common enemies fell down; The low attended wheat had high densities of aphids that immigrated to the tomato cultivation. Crowding is the most important factor leading to the developments of alates (winged forms) of aphids (Malais and Ravensberg, 2003).

On the other hand, the sulfur that was used is permitted in organic farming, although the producers in Denmark do not use it against spider mites (Klaus Sogård, Markhaven Aps). Sulfur had encouraging results from the first moment, despite the climatic conditions. Although the mechanism of its action on mites remains obscure, it has been reported that a minimum of 17 ^{o}C is necessary to observe its acaricidal effect (Auger *et al*., 2003). While sulfur's impact on spider mites is well-known, its efficiency depends on sulfur formulation, dosage applied and environmental conditions (Auger *et al*., 2003). Nevertheless, even under conditions consisting of low temperatures and low humidities, the use of sulfur had always encouranging effects, by reducing protonymphs populations by half, than those of controls in laboratory conditions (Auger *et al*., 2003). Furthermore, the assumption that sulfur was the reason why *P. persimilis* did not have encouraging results can be denied from Koppert's (Koppert B.V., Netherlands) internet guide (http://www.koppert.nl/cgi-bin/x0225.pl?lang=e&filter1=396%2316&filter2=28), that sulfur has slightly harmful effect on its adult population. However, sulfur toxicity on mites of the Phytoseiidae family, still remain obscure as results are conflincting (Auger *et al*., 2003).

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Appendix II: Data Analysis

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The GLM Procedure

Class Level Information

Class	Levels	Values
planting	2	1 2
water	4	1 2 3 4

Number of observations 40

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The GLM Procedure

Dependent Variable: Ia

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	31590661.58	4512951.65	5.93	0.0002
Error	32	24333796.40	760431.14		
Corrected Total	39	55924457.98			

R-Square	Coeff Var	Root MSE	Ia Mean
0.564881	18.65987	872.0270	4673.275

Source	DF	Type I SS	Mean Square	F Value	Pr > F
planting	1	9673706.03	9673706.03	12.72	0.0012
water	3	18469331.68	6156443.89	8.10	0.0004
planting*water	3	3447623.88	1149207.96	1.51	0.2304

Source	DF	Type III SS	Mean Square	F Value	Pr > F
planting	1	9673706.03	9673706.03	12.72	0.0012
water	3	18469331.68	6156443.89	8.10	0.0004
planting*water	3	3447623.88	1149207.96	1.51	0.2304

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The GLM Procedure

Dependent Variable: height

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	77528.70000	11075.52857	48.79	<.0001
Error	32	7264.80000	227.02500		
Corrected Total	39	84793.50000			

R-Square	Coeff Var	Root MSE	height Mean
0.914324	8.068192	15.06735	186.7500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
planting	1	220.90000	220.90000	0.97	0.3313
water	3	76574.90000	25524.96667	112.43	<.0001
planting*water	3	732.90000	244.30000	1.08	0.3731

Source	DF	Type III SS	Mean Square	F Value	Pr > F
planting	1	220.90000	220.90000	0.97	0.3313
water	3	76574.90000	25524.96667	112.43	<.0001
planting*water	3	732.90000	244.30000	1.08	0.3731

The GLM Procedure

Dependent Variable: diameter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	12.90575000	1.84367857	6.78	<.0001
Error	32	8.70400000	0.27200000		
Corrected Total	39	21.60975000			

R-Square	Coeff Var	Root MSE	diameter Mean
0.597219	4.247902	0.521536	12.27750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
planting	1	0.21025000	0.21025000	0.77	0.3859
water	3	11.80475000	3.93491667	14.47	<.0001
planting*water	3	0.89075000	0.29691667	1.09	0.3668

Source	DF	Type III SS	Mean Square	F Value	Pr > F

planting	1	0.21025000	0.21025000	0.77	0.3859
water	3	11.80475000	3.93491667	14.47	<.0001
planting*water	3	0.89075000	0.29691667	1.09	0.3668

The GLM Procedure

Dependent Variable: trusses

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	87.6000000	12.5142857	17.56	<.0001
Error	32	22.8000000	0.7125000		
Corrected Total	39	110.4000000			

R-Square	Coeff Var	Root MSE	trusses Mean
0.793478	10.16985	0.844097	8.300000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
planting	1	1.60000000	1.60000000	2.25	0.1438
water	3	85.40000000	28.46666667	39.95	<.0001
planting*water	3	0.60000000	0.20000000	0.28	0.8389

Source	DF	Type III SS	Mean Square	F Value	Pr > F
planting	1	1.60000000	1.60000000	2.25	0.1438
water	3	85.40000000	28.46666667	39.95	<.0001
planting*water	3	0.60000000	0.20000000	0.28	0.8389

The GLM Procedure

Dependent Variable: nodes

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	498.3750000	71.1964286	19.71	<.0001
Error	32	115.6000000	3.6125000		
Corrected Total	39	613.9750000			

R-Square	Coeff Var	Root MSE	nodes Mean
0.811719	6.077243	1.900658	31.27500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
planting	1	3.0250000	3.0250000	0.84	0.3670
water	3	491.8750000	163.9583333	45.39	<.0001
planting*water	3	3.4750000	1.1583333	0.32	0.8104

Source	DF	Type III SS	Mean Square	F Value	Pr > F
planting	1	3.0250000	3.0250000	0.84	0.3670
water	3	491.8750000	163.9583333	45.39	<.0001
planting*water	3	3.4750000	1.1583333	0.32	0.8104

The GLM Procedure

Dependent Variable: Sdw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1774.017750	253.431107	108.80	<.0001
Error	32	74.540000	2.329375		
Corrected Total	39	1848.557750			

R-Square	Coeff Var	Root MSE	Sdw Mean
0.959677	6.348046	1.526229	24.04250

Source	DF	Type I SS	Mean Square	F Value	Pr > F
planting	1	125.670250	125.670250	53.95	<.0001
water	3	1615.158750	538.386250	231.13	<.0001
planting*water	3	33.188750	11.062917	4.75	0.0075

Source	DF	Type III SS	Mean Square	F Value	Pr > F
planting	1	125.670250	125.670250	53.95	<.0001
water	3	1615.158750	538.386250	231.13	<.0001
planting*water	3	33.188750	11.062917	4.75	0.0075

The GLM Procedure

Dependent Variable: Ldw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	3657.245750	522.463679	59.61	<.0001
Error	32	280.484000	8.765125		

Corrected Total	39	3937.729750

R-Square	Coeff Var	Root MSE	Ldw Mean
0.928770	9.223757	2.960595	32.09750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
planting	1	401.322250	401.322250	45.79	<.0001
water	3	3229.658750	1076.552917	122.82	<.0001
planting*water	3	26.264750	8.754917	1.00	0.4060

Source	DF	Type III SS	Mean Square	F Value	Pr > F
planting	1	401.322250	401.322250	45.79	<.0001
water	3	3229.658750	1076.552917	122.82	<.0001
planting*water	3	26.264750	8.754917	1.00	0.4060

The GLM Procedure
Least Squares Means

planting	la LSMEAN	H0:LSMean1=LSMean2 t Value	Pr > |t|
1	4181.50000	-3.57	0.0012
2	5165.05000		

planting	height LSMEAN	H0:LSMean1=LSMean2 t Value	Pr > |t|
1	184.400000	-0.99	0.3313
2	189.100000		

planting	diameter LSMEAN	H0:LSMean1=LSMean2 t Value	Pr > |t|
1	12.2050000	-0.88	0.3859
2	12.3500000		

planting	trusses LSMEAN	H0:LSMean1=LSMean2 t Value	Pr > |t|
1	8.50000000	1.50	0.1438
2	8.10000000		

planting	nodes LSMEAN	H0:LSMean1=LSMean2 t Value	Pr > |t|
1	31.5500000	0.92	0.3670
2	31.0000000		

H0:LSMean1=LSMean2

planting	Sdw LSMEAN	t Value	Pr > |t|
1	25.8150000	7.35	<.0001
2	22.2700000		

H0:LSMean1=LSMean2

planting	Ldw LSMEAN	t Value	Pr > |t|
1	35.2650000	6.77	<.0001
2	28.9300000		

The GLM Procedure
Least Squares Means

water	la LSMEAN	LSMEAN Number
1	3568.60000	1
2	4875.10000	2
3	4826.10000	3
4	5423.30000	4

Least Squares Means for Effect water
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: la

i/j	1	2	3	4
1		-3.35015	-3.2245	-4.75586
		0.0021	0.0029	<.0001
2	3.350152		0.125647	-1.4057
	0.0021		0.9008	0.1694
3	3.224505	-0.12565		-1.53135
	0.0029	0.9008		0.1355
4	4.755856	1.405705	1.531351	
	<.0001	0.1694	0.1355	

water	height LSMEAN	LSMEAN Number
1	127.500000	1
2	163.700000	2
3	217.200000	3
4	238.600000	4

Least Squares Means for Effect water
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: height

i/j	1	2	3	4
1		-5.37226	-13.3119	-16.4878
		<.0001	<.0001	<.0001
2	5.372256		-7.93966	-11.1155
	<.0001		<.0001	<.0001
3	13.31192	7.939661		-3.17586
	<.0001	<.0001		0.0033
4	16.48778	11.11552	3.175864	
	<.0001	<.0001	0.0033	

The GLM Procedure
Least Squares Means

water	diameter LSMEAN	LSMEAN Number
1	11.5800000	1
2	12.0100000	2
3	12.4800000	3
4	13.0400000	4

Least Squares Means for Effect water
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: diameter

i/j	1	2	3	4
1		-1.84361	-3.85872	-6.2597
		0.0745	0.0005	<.0001
2	1.84361		-2.01511	-4.41609
	0.0745		0.0524	0.0001
3	3.858718	2.015108		-2.40098
	0.0005	0.0524		0.0223
4	6.259698	4.416089	2.40098	
	<.0001	0.0001	0.0223	

water	trusses LSMEAN	LSMEAN Number
1	6.2000000	1
2	7.8000000	2
3	9.1000000	3
4	10.1000000	4

Least Squares Means for Effect water
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: trusses

i/j	1	2	3	4

i/j	1	2	3	4
1		-4.2385	-7.68229	-10.3314
		0.0002	<.0001	<.0001
2	4.238504		-3.44378	-6.09285
	0.0002		0.0016	<.0001
3	7.682288	3.443784		-2.64906
	<.0001	0.0016		0.0124
4	10.33135	6.092849	2.649065	
	<.0001	<.0001	0.0124	

The GLM Procedure
Least Squares Means

water	nodes LSMEAN	LSMEAN Number
1	26.6000000	1
2	29.5000000	2
3	33.2000000	3
4	35.8000000	4

Least Squares Means for Effect water
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: nodes

i/j	1	2	3	4
1		-3.41176	-7.76471	-10.8235
		0.0018	<.0001	<.0001
2	3.411765		-4.35294	-7.41176
	0.0018		0.0001	<.0001
3	7.764706	4.352941		-3.05882
	<.0001	0.0001		0.0045
4	10.82353	7.411765	3.058824	
	<.0001	<.0001	0.0045	

water	Sdw LSMEAN	LSMEAN Number
1	15.0100000	1
2	21.2200000	2
3	29.0500000	3
4	30.8900000	4

Least Squares Means for Effect water
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: Sdw

i/j	1	2	3	4
1		-9.09823	-20.5699	-23.2657
		<.0001	<.0001	<.0001
2	9.09823		-11.4717	-14.1675

	<.0001		<.0001	<.0001
3	20.56991	11.47168		-2.69577
	<.0001	<.0001		0.0111
4	23.26568	14.16745	2.695772	
	<.0001	<.0001	0.0111	

The GLM Procedure
Least Squares Means

water	Ldw LSMEAN	LSMEAN Number
1	18.8900000	1
2	29.1000000	2
3	38.1700000	3
4	42.2300000	4

Least Squares Means for Effect water
t for H0: LSMean(i)=LSMean(j) / Pr > |t|

Dependent Variable: Ldw

i/j	1	2	3	4
1		-7.71137	-14.5617	-17.6282
		<.0001	<.0001	<.0001
2	7.711373		-6.85036	-9.91678
	<.0001		<.0001	<.0001
3	14.56173	6.850357		-3.06642
	<.0001	<.0001		0.0044
4	17.62815	9.91678	3.066422	
	<.0001	<.0001	0.0044	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

The GLM Procedure

t Tests (LSD) for la

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	760431.1
Critical Value of t	2.03693
Least Significant Difference	561.7

Means with the same letter are not significantly different.

t Grouping	Mean	N	planting
A	5165.1	20	2
B	4181.5	20	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for la

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	760431.1
Critical Value of Studentized Range	2.88068
Minimum Significant Difference	561.71

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	planting
A	5165.1	20	2
B	4181.5	20	1

The GLM Procedure

t Tests (LSD) for height

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	227.025
Critical Value of t	2.03693
Least Significant Difference	9.7054

Means with the same letter are not significantly different.

t Grouping	Mean	N	planting
A	189.100	20	2
A			
A	184.400	20	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for height

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	227.025
Critical Value of Studentized Range	2.88068
Minimum Significant Difference	9.7055

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	planting
A	189.100	20	2
A			
A	184.400	20	1

The GLM Procedure

t Tests (LSD) for diameter

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.272
Critical Value of t	2.03693
Least Significant Difference	0.3359

Means with the same letter are not significantly different.

t Grouping	Mean	N	planting
A	12.3500	20	2
A			
A	12.2050	20	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for diameter

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05

Error Degrees of Freedom 32
Error Mean Square 0.272
Critical Value of Studentized Range 2.88068
Minimum Significant Difference 0.3359

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	planting
A	12.3500	20	2
A			
A	12.2050	20	1

The GLM Procedure

t Tests (LSD) for trusses

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05
Error Degrees of Freedom 32
Error Mean Square 0.7125
Critical Value of t 2.03693
Least Significant Difference 0.5437

Means with the same letter are not significantly different.

t Grouping	Mean	N	planting
A	8.5000	20	1
A			
A	8.1000	20	2

The GLM Procedure

Tukey's Studentized Range (HSD) Test for trusses

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha 0.05
Error Degrees of Freedom 32
Error Mean Square 0.7125
Critical Value of Studentized Range 2.88068
Minimum Significant Difference 0.5437

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	planting
A	8.5000	20	1
A			
A	8.1000	20	2

The GLM Procedure

t Tests (LSD) for nodes

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	3.6125
Critical Value of t	2.03693
Least Significant Difference	1.2243

Means with the same letter are not significantly different.

t Grouping	Mean	N	planting
A	31.5500	20	1
A			
A	31.0000	20	2

The GLM Procedure

Tukey's Studentized Range (HSD) Test for nodes

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	3.6125
Critical Value of Studentized Range	2.88068
Minimum Significant Difference	1.2243

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	planting
A	31.5500	20	1
A			
A	31.0000	20	2

The GLM Procedure

t Tests (LSD) for Sdw

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	2.329375
Critical Value of t	2.03693
Least Significant Difference	0.9831

Means with the same letter are not significantly different.

t Grouping	Mean	N	planting
A	25.8150	20	1
B	22.2700	20	2

The GLM Procedure

Tukey's Studentized Range (HSD) Test for Sdw

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	2.329375
Critical Value of Studentized Range	2.88068
Minimum Significant Difference	0.9831

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	planting
A	25.8150	20	1
B	22.2700	20	2

The GLM Procedure

t Tests (LSD) for Ldw

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	8.765125
Critical Value of t	2.03693
Least Significant Difference	1.907

Means with the same letter are not significantly different.

t Grouping	Mean	N	planting
A	35.2650	20	1
B	28.9300	20	2

The GLM Procedure

Tukey's Studentized Range (HSD) Test for Ldw

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	8.765125
Critical Value of Studentized Range	2.88068
Minimum Significant Difference	1.907

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	planting
A	35.2650	20	1
B	28.9300	20	2

The GLM Procedure

t Tests (LSD) for la

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	760431.1
Critical Value of t	2.03693
Least Significant Difference	794.37

Means with the same letter are not significantly different.

t Grouping	Mean	N	water
A	5423.3	10	4
A			
A	4875.1	10	2
A			
A	4826.1	10	3
B	3568.6	10	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for la

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	760431.1
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	1056.6

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	water
A	5423.3	10	4
A			
A	4875.1	10	2
A			
A	4826.1	10	3
B	3568.6	10	1

The GLM Procedure

t Tests (LSD) for height

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	227.025
Critical Value of t	2.03693
Least Significant Difference	13.726

Means with the same letter are not significantly different.

t Grouping	Mean	N	water
A	238.600	10	4
B	217.200	10	3
C	163.700	10	2
D	127.500	10	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for height

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	227.025
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	18.257

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	water
A	238.600	10	4
B	217.200	10	3
C	163.700	10	2
D	127.500	10	1

The GLM Procedure

t Tests (LSD) for diameter

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.272
Critical Value of t	2.03693
Least Significant Difference	0.4751

Means with the same letter are not significantly different.

```
t Grouping        Mean      N    water

      A      13.0400     10    4

      B      12.4800     10    3
      B
  C   B      12.0100     10    2
  C
  C          11.5800     10    1
```


The GLM Procedure

Tukey's Studentized Range (HSD) Test for diameter

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.272
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	0.6319

Means with the same letter are not significantly different.

```
Tukey Grouping        Mean      N    water

      A      13.0400     10    4
      A
  B   A      12.4800     10    3
  B
  B   C      12.0100     10    2
      C
      C      11.5800     10    1
```


The GLM Procedure

t Tests (LSD) for trusses

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.7125
Critical Value of t	2.03693
Least Significant Difference	0.7689

Means with the same letter are not significantly different.

t Grouping	Mean	N	water
A	10.1000	10	4
B	9.1000	10	3
C	7.8000	10	2
D	6.2000	10	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for trusses

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.7125
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	1.0228

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	water
A	10.1000	10	4
A			
A	9.1000	10	3
B	7.8000	10	2
C	6.2000	10	1

The GLM Procedure

t Tests (LSD) for nodes

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	3.6125
Critical Value of t	2.03693
Least Significant Difference	1.7314

Means with the same letter are not significantly different.

t Grouping	Mean	N	water
A	35.8000	10	4
B	33.2000	10	3
C	29.5000	10	2
D	26.6000	10	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for nodes

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	3.6125
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	2.303

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	water
A	35.8000	10	4
B	33.2000	10	3
C	29.5000	10	2
D	26.6000	10	1

The GLM Procedure

t Tests (LSD) for Sdw

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	2.329375
Critical Value of t	2.03693
Least Significant Difference	1.3903

Means with the same letter are not significantly different.

t Grouping	Mean	N	water
A	30.8900	10	4
B	29.0500	10	3
C	21.2200	10	2
D	15.0100	10	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for Sdw

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	2.329375
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	1.8493

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	water
A	30.8900	10	4
A			
A	29.0500	10	3
B	21.2200	10	2
C	15.0100	10	1

The GLM Procedure

t Tests (LSD) for Ldw

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	8.765125
Critical Value of t	2.03693
Least Significant Difference	2.6969

Means with the same letter are not significantly different.

t Grouping	Mean	N	water
A	42.230	10	4
B	38.170	10	3
C	29.100	10	2
D	18.890	10	1

The GLM Procedure

Tukey's Studentized Range (HSD) Test for Ldw

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	8.765125
Critical Value of Studentized Range	3.83162
Minimum Significant Difference	3.5872

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	water
A	42.230	10	4
B	38.170	10	3
C	29.100	10	2
D	18.890	10	1