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# Effect of grafting runner beans on crop yield and fruit quality

Master in Organic Farming

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# ABSTRACT

Runner bean is a popular vegetable culture. It is often cultivated in green houses. To intensify its production, synthetic fertilizers along with pesticides are often used. However, using grafting can effectively and inexpensively fight root parasites and increase the uptake of nutrients from the soil, due to the development of a stronger root system of the plant. This method has previously shown promising results for tomatoes.

In this work we have studied how grafting of runner beans cultivars Rajado and Oriente on the rootstocks P1: cv. Aintree (Tozer Seeds), P2: cv. White Emergo (TS), and P3: cv. feijão de 7 anos (Portuguese landrace cv.) can affect plant performance, yield and resistance of the crop to soil borne disease, such as nematodes and Fusarium.

We recorded the number of days after planting (DAP) at which the first flower and the first pod occurred in each crop treatment. Also we measured the length of the pods, their fresh and dry weights, and the frequency of diseases and defects on the pods. The temperature and relative humidity inside the greenhouse were constantly measured.

During the experiment the plants experienced nutrient deficiency and *Fusarium solani* infection. The plants grafted onto the R3 rootstock, cv. feijão de 7 anos, have shown the best survival rates and yield per plant.

In conclusion, grafting runner bean seems to be an appropriate strategy to increase crop tolerance to soilborne diseases caused by *Fusarium* spp. and nutrient deficiency, mainly for higher yielding cultivars such as cv. Oriente. For the scion cv. Oriente we would recommend the rootstock cv. P3, while for cv. Rajado further investigation is still needed to evaluate the effects of rootstocks P2 and P3.

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## 1. Introduction

In the period from the 1940s to the 1960s, a revolution in agricultural practices and technologies were introduced globally. Farmers, particularly in developing countries, started to use high-yielding varieties, irrigation infrastructures, pesticides, herbicides, and synthetic fertilizers, which effectively boosted food production in the short term. This process, the **Green Revolution,** was renowned for reducing human hunger in Mexico, India and Pakistan in the 1960s, and this won Dr. Norman Borlaug, the 'Father of the Green Revolution' the Nobel Peace Prize in 1970 (Nobel Prize). But, these rapid advances in agronomy made food production highly intensive and dependent on chemicals and machines; it quickly became market-driven, and failed to take into account local knowledge and culture, and the ecology of agricultural ecosystems (Gliessman, 2013).

Growing a monoculture and placing high artificial selection on more productive plants, over pest and disease resistance, lead to the increase on the occurrence and severity of pests and diseases, with a corresponding yield decrease. In Europe, this varies from 20-35%, depending on the part of the continent (Oerke, 2005). Keeping all the pests and diseases under control using large quantities of pesticides is no longer an option, as these chemicals are often harmful for the consumers and the environment. Until recent time using pesticides, and particularly soil fumigation with Methyl Bromine, was considered one of the main factors for the production success in greenhouses, as an effective way to control soil-borne diseases. But after the **Montreal Protocol** ratification (1987) the use of ozone-depleting chemicals, including **methyl bromine**, was phased out worldwide. The restrictions, made since by the Montreal protocol, have been shown to be effective in protecting the Ozone layer (Mäder, 2010). Methyl bromide was banned in Europe, but a further global prohibition can be expected, which gives an additional market to some alternative pesticides (EPA, 2015), many of which are also toxic and bound to be banned in the next 20 years (Nicol et al., 2010).

A sustainable and ecologically-sound management of the agricultural ecosystems, which builds on scientific knowledge, technology and social-driven practices, must be put in place to prevent pest and disease populations to increase and become more problematic (Gliessman, 2013).

The principles of organic farming, set out in the EU Legislation (EC 834/2007), aim to improve the sustainability of cultivation systems, offer a variety of high-quality products, place a greater emphasis on environmental protection, and give more attention to biodiversity. A concern with human health and social wellbeing is also patent in the EU legislation, in aiming to increase consumer confidence in organic farming and protecting consumer interests.

In organic farming, pest and disease control is done by the use of resistant varieties, biological control, changing the ecological conditions to make it less favorable for pests, using some biological pesticides only when plants are attacked, and by constant monitoring for and removal of infected plants (Hills, 1989). Among these control methods, **biological control** makes use of existing, natural interactions between pests and diseases and their natural consumers, i.e., it is the encouragement of beneficial organisms already existing locally or the introduction of new species of beneficial organisms to bring down populations of a given pest or disease to a non-damaging level. Fighting the pest by changing the ecological conditions is done by growing **mixed cultures** on one field rather than a monoculture, and crop rotation. It is allowed in organic farming to use the natural products **biological pesticides**. For example extracts from plants, such as pyrethrum and daisy, or bacteria, e.g. *Bacillus thuringiensis.*

The use of **resistant cultivars** is an old and can be an effective method to fight pests and diseases. It is commonly used for horticulture and cereals. However sometimes it is hard to find a resistant cultivar with acceptable yield of desirable characteristics. This control method can have further limitations: the resistant cultivars are frequently only partially resistant and some pests can overcome the resistance. For example, root-knot nematodes *Meloidogyne spp.* can parasitise most of the flowering plants, and, despite their asexual reproduction, can express different parts of their genome to fit the environment, due to high portion of transposable elements in their genome, along with presence of homologous but divergent DNA segments (Castagnone, 2014). Also resistant cultivars can lose their resistance as a consequence of unfavorable environment conditions. For example, three out of eleven studied tomato cultivars, resistant against root-knot nematodes, have significantly increased their susceptibility toward *Meloidogyne arenaria* and *Meloidogyne javanica* after a heat stress. It was found that the *Mi* gene in tomato, which confers resistance to *Meloidogyne* sp. attack, ceases it expression at soil temperatures above 28°C (Verdejo-Lucas, 2013).

## 1.1 - Vegetable grafting

Where pest and/or disease –resistant cultivars are available, but with limited yield or with no commercial value, these can be used as rootstock cultivars onto which the commercially-producing cultivars can be grafted.

Grafting has historically been done on fruit trees, and has a special value in fruit culture, where the raising of resistant varieties is made difficult by the slow growth of the trees. A good example of the successful usage of grafting for plant protection is the **Phylloxera** pest of grape vine (*Vitis vinifera*). In 1865 all the vine industry of France was threatened by the pest bug Phylloxera (*Phylloxera vitifolii Fitch*). The Californian vine, *V. californica*, is immune to the pest which is now controlled by grafting European cultivars to American rootstocks (Hubert, 1983).

Vegetable grafting, already used in ancient times in Japan, is still very recent in Europe, and has been growing increasingly since the 2000s. It can help vegetable plants to cope with soil-based stresses: not only soil borne pathogens, but also inadequate abiotic conditions (salt, temperature). Industrial application of grafted vegetable plants started in late 1920-ths in Eastern Asia – Japan and Korea. The most popular vegetables for grafting are watermelon, cucumber, melon, tomato and eggplant. Later this technique has been progressively used throughout Europe and worldwide. In Portugal the vegetable grafting was first introduced in tomato plants, where it is estimated that, by 2009, half of the commercial production of fresh tomato was being grown on grafted plants (FLF, 2010). Grafted watermelons, melons and cucumbers are also very common (Rodrigues, 2009). The most popular for grafting vegetables are cucurbits and solanaceous families (Lee et al, 2010).

An interesting field in the science and technology of grafting is the development of **grafting robots**. According to (McClure, 2008), semi- or fully-automated grafting robots were invented by several agricultural machine industries in the 1990s, yet the available models are limited. The lack of flexibility of the existing robots also limits their wider use.

There are very recent articles about improving the efficiency of grafting robots. In the journal of robotics the developed grafting robot was described. It is capable of clipping, moving, positioning, cutting, grafting, and binding saplings. Experiments show that the stock cutting efficiency is 98.4%, the scion cutting efficiency is 98.9%, the grafting efficiency is 87.3%, and the binding efficiency is 68.9%. (Qun Sun, 2014). So, in perspective, the automated grafting can be used to decrease the price of the grafted plants. Currently grafting robots are still not used widely due to pathogen problems: if one of the plants is infected, the robot blade will spread the infection through all the plants it cuts.

### 1.1.1 - Advantages of grafting

The use of grafting can bring about many advantages. Grafting may be used to **boost plant growth and development**. It was shown that the rootstock genotype determines the yield, and the macronutrients content in the leave of the scion, primary N and Na (Ruiz, 1997). For this reason, the planting **density** of grafted plants could be **half the conventional**, and still provide high yields due to increased plant vigor. Grafted plants usually need **less fertilizer** due to the powerful root system (Rodrigues, 2010). It is recommended to decrease the use of fertilizers by 30% or more for grafted comparing to self-rooted plants, depending of the rootstock cultivar (Lee and Oda, 2003; Salehi-Mohammadi, 2009). Grafting also can help to **extend harvest period** and **increase the yield** (Lee et al, 2010).

Grafted plants also can be used to allow agricultural production in **hot-wet season**. It was shown, that tomatoes grafted on eggplant rootstock can tolerate floods, waterlogged soils, and soil borne diseases much better than ungrafted ones. Using grafted tomatoes can reduce the yield loss or even plants death during floods (Black, 2003). It was also shown, that grafting can be used to increase the plant tolerance to **low temperatures** (Rivero, 2003)). Grafting cucumbers on low temperature resistant rootstock can promote plant growth and early fruit production in suboptimal temperatures in winter (Nijs, 1984).

An exciting outcome of research on vegetable grafting, especially for cultivation in greenhouses, is the use of grafting to obtain plants **resistant to salinity** of the soil. Soil salinity has two separate effects - osmotic or an ion-specific effect, which cannot be fully separated. The osmotic effect is always proportional to salt concentration. The ion-specific effect is based on the fact that different ions can interfere with the uptake of the essential ions e.g. $K^+$, $Ca^{2+}$, $Mg^{2+}$ (Colla, 2012). Salinity can be problematic in greenhouses, as leaching of soil additives is reduced. Besides **NaCl salinity**, there are problems with **$NaSO_4$ salinity** in parts of India, Egypt and California. In saline conditions, grafted plants can perform much better than ungrafted ones by many parameters, such as shoots nutritional status and net assimilation rate. Thus far, grafting is more effective against $NaSO_4$ salinity than against high NaCl levels (Colla, 2012). In his article, Dimitrios Savvas shows, that grafting tomatoes on commercial rootstocks (Beaufort, He-Man, Resistar) can prevent a yield loss at low (22 mM NaCl) and moderate (45 mM NaCl) soil salinity levels. The plants grafted onto two of the tested rootstocks gave higher yields only in comparison with the nongrafted plants, and the differences were significant only at low (Beaufort) or moderate (Resistar) salinity. Yield differences between grafting treatments at low and moderate salinity arose from differences in fruit number per plant, while mean fruit weight was not influenced by grafting or the rootstock. NaCl salinity had no effect on the yield of plants grafted onto He-Man but restricted the yield in all other grafting treatments due to reduction of the mean fruit weight. Grafting onto the three tested commercial rootstocks significantly reduced the leaf Mg concentrations, resulting in clear Mg-deficiency symptoms 19 weeks after planting (Savvas, 2011). Using grafting to improve the salinity resistance is developed for such vegetables as tomatoes, cucumber, squash and bottle gourd, melon, watermelon, eggplant (Rouphael, 2010).

Grafting also affects the **quality of fruits**. If on one hand it can increase fruit quality and increase the yield of commercial fruits, change their colour and increase their size, on the other hand the rootstock can also affect their taste: in a so far ill-explained phenomenon, watermelon plants grafted onto pumpkin can produce watermelons with a hint of cucurbit taste (Lee, 2003). In fact, in 2012 it was proven that genetic information may migrate from rootstock to scion through grafting. Transfer of entire chloroplasts, or at least their genomes, can occur in contact zones between plants. The new chloroplast genome can even be handed down to the next generation and, thereby, result in a plant with new traits. These findings are of great importance to the understanding of evolution as well as the breeding of new plant varieties, and above all to grafting itself (Stegemann, 2012).

**Grafting** can provide multiple **advantages over self-rooting** in some plant species, other than vegetables**.** Grafted scions provide larger numbers of plants compared to rooted cuttings and more shoots can be taken from the donor parents for grafting than for cuttings. The significantly reduced time to establish grafted scions compared with rooted cuttings is another advantage of grafting compared with rooting. Grafting could potentially help with the **propagation and perpetuation of sterile or recalcitrant interspecific hybrids**, and could also be used to increase seed multiplication in determinate type beans (Gurusamy, 2010).

Importantly, grafting has been described as an effective and eco-friendly way to control **soil borne diseases** in tomatoes, watermelons, melons, cucumbers, peppers, eggplants, and other horticultural plants. The former include: fungal pathogens *Verticillium*, *Fusarium*, *Pyrenochaeta* and *Monosporascus*; oomycete pathogens like *Phytophthora*; bacterial pathogens, particularly *Ralstonia*; root knot nematodes *Meloidogyne* sp. and several soil-borne virus pathogens. fusarium wilt, bacterial wilt, verticillium wilt, monosporascus root rot, and nematodes" (Louws, 2010). Grafting can also increase tolerance to foliar fungal diseases, viruses, and insects (King, 2008). This makes the use of grafted plants appealing also for **hydroponics** farming, as in such systems there are high chances of rapid spread of diseases (Lee et al, 2010).

### 1.1.2 - Methods of vegetable grafting

For successful grafting the scion and the stock should be compatible and produce a single, functioning plant. When two pieces of stem tissue fuse together in growth from the meristematic area, there is a line, or point, or plane at which the adjacent cells originated from two different sources. The xylem and phloem tissues on either side of this line should be similar enough to permit the passage of nutrients and water through the graft union. Incompatible grafts will sometimes fuse and grow, but normal development is restricted to some extent.

Before grafting it is important to make sure that the grafted plants are turgid. When grafting in greenhouses it is better to graft in the morning or in the evening to avoid water stress. The place for grafting should be shadowed and not windy (McAvoy, 2015). Maintaining the moisture content of rootstock and scion is an important rule for success in producing grafted plants. In the aerial parts of the plant, water loss is prevented by using a grafting compound or rubber tape. Placing in an atmosphere of 100 percent relative humidity prevents water loss from grafted herbaceous plants.

The point of the graft should be above ground level, so that the commercial variety does not send roots and soil-borne diseases are handled by the rootstock. However, the graft needs to be done below the rootstock cotyledons, as this prevents the occurrence of **suckering** - rootstock shoot regrowth (Bausher, 2011).

Both the scion and the rootstock should be cut at the same angle to promote a full contact between the rootstock and scion. Accordingly, the diameter of the scion and the rootstock should be approximately equal at the union point and they should be in tight contact before clipping is put in place, to match all the vascular tissues (McAvoy, 2015). For successful grafting it is very **important to match all the plant's vascular tissues** (Fig. 1.1). The **Xylem** provides the movement of water and nutrients from the roots to the top of the plant. The **Phloem** ditributes sugars and hormones produced in the leaves throughout the plant. The **Cambium (meristem)** is where the stem growth in diameter takes place. Finally, the union of the two plant parts should be done as quickly as possible after cutting, as waiting for more than a few minutes after the cut was done can hinder success.

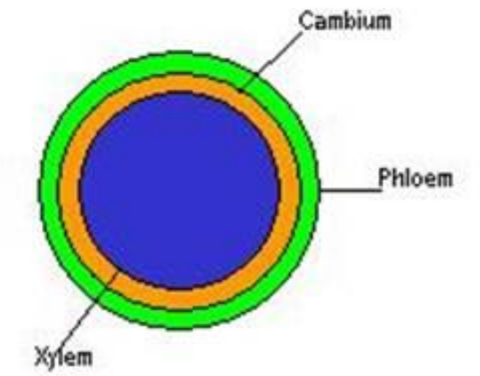


*Figure 1.1 - The vascular tissues (McAvoy, 2015)*

It is important to provide proper **healing and acclimatization** for grafted plants in order for them to survive. The grafted plants should be kept in relative humidity of 95% or more for 3-5 days until the cut ends knit together, or heal. Usually the grafted plants are placed in a special tent for **shadowing**. Pressure **sprayers** are often used for misting twice a day to provide proper humidity (McAvoy, 2015).

### Cleft Grafting

For grafting with the cleft graft methods the rootstock should be sown 5-7 days prior to the scion plants. When the rootstock reaches the 5-6 leaves stage, the stem from both the scion and the rootstock with 2-3 leaves remaining are cut. The scion is cut in a wedge shape and placed into the cleft cut in the end of the rootstock. Then the graft is held firmly with a clip Fig. 1.2) (McAvoy, 2015).

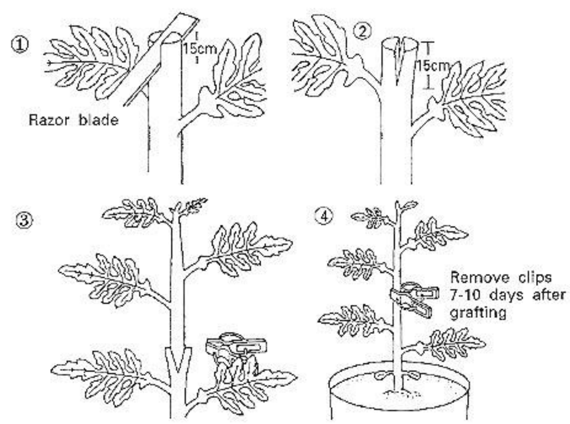


*Figure 1.2 - Cleft Grafting (Masayuki, 1999)*

### Tongue Approach Grafting

This technique provides high grafting success rates, and because of this it is often used to graft melons, cucumbers, and other Cucurbitaceous species. It is also used for tomatoes, when there are no facilities to provide good healing conditions.

To perform this method older plants are needed, with sufficient stem diameter. The top of the rootstock is removed, then both the scion and the rootstock are cut in a tongue shape, connected and fixed with a larger clip. After healing for 3-4 days the scion is cut off from its original root and left on the rootstock *(Fig. 1.3) (McAvoy, 2015)*.

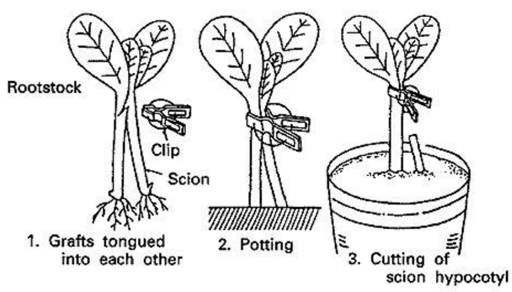


*Figure 1.3 - Tongue Approach Grafting (Masayuki, 1999)*

Besides the high success rate of plant union, approach grafting provides the lowest rate of rootstock shoots developing in the field as compared to other grafting techniques. However it is more time-consuming and laborious than other grafting methods.

**Tube Grafting**

For this grafting method the rootstock should be sown 1-2 days before the scion. Tube grafting is suitable for young plants. The grafting speed of this technique is 2-3 times faster than with the cleft grafting and grafted plants require less space in the healing facilities.

It is good to start grafting when the scion has developed one pair of true leaves. Before grafting the tubes with the diameter that matches the stems diameter should be chosen. Then the rootstock should be cut with a razor blade at 30-45°. The cut should be done **below the cotyledons**. **Otherwise** there is a risk of **the axillary buds** development. Then a tube should be placed on the rootstock on a half of its length. After that the scion is cut at the same angle as the rootstock and then placed in the tube in tight contact with the cut on the rootstock.

It is important to mist the grafted plant to prevent desiccation. Healing takes 4-7 days, and after healing the scion part of the grafted plant often is **pinched** to develop two **axillary shoots**. As with other grafting techniques, it is important that the diameters of the scion and the rootstock are approximately the same size. Also the tube should be chosen to match the diameter of the stems (Fig. 1.4) (Kubota, 2015).

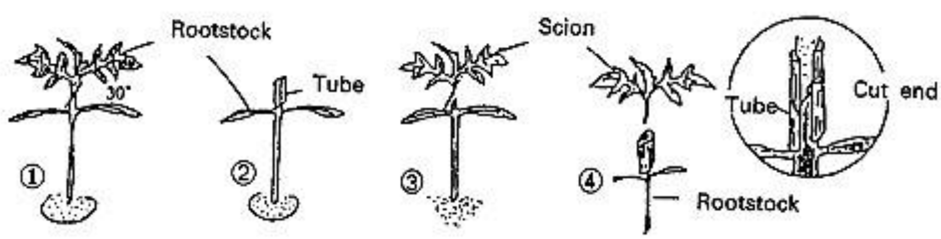


*Figure 1.4 - Tube Grafting (McAvoy, 2015)*

## 1.2 - Runner beans

### 1.2.1 - Runner beans description

Runner beans (*Phaseolus coccineus*, feijão-verde) is a plant in the *Fabaceae* family (previously Leguminosae) or the bean family. Although it is mainly grown for food, there are also some ornamental cultivars. Like other members of legume family, the bean plant forms associations with nitrogen fixing bacteria (rhizobia) in its roots. The bean is day neutral – its flowering and pod set are unaffected by day length.

This species originated from the mountains of Central America. Most varieties have red flowers and multicolored seeds, though some have white flowers and white seeds. The vine can grow to 2 m, and in some cultivars – as long as 4 meters. Bush types exist, dwarfness being an inherited trait. The beans from non-climbing bush or dwarf runner beans are considered lower-quality comparing to the ones produced by the climber cultivars. However the non-climbing beans are easier to harvest (RHS, 2015). The root system has a thick taproot and is fibrous. The knife-shaped pods are normally green. Protein content of the mature seed is about 17%, with carbohydrate content about 65%.

The species is perennial, but it is usually grown in production systems in Europe as an annual. Like other *Phaselous*, runner beans are frost-sensitive, and the the optimal mean daily temperature remains between 15° and 30° C. Temperatures below or above the range can have deleterious effect on the performance of the bean plant. Below 0° C and above 35° C germination does not occur, whereas in the appropriate temperature range, beans will germinate in under six days. Production of fresh pods is more possible in cold climate then seed production. Windy and rainy climate is unfavorable, because it increases spread of foliar diseases (Nonnecke, 1989).

For proper development, runner beans need large amounts of water, especially if the weather is dry when the buds start to appear. It is recommended to apply 5-9 liters of water per square metre every three to four days during the farming season. When the bean shoots have reached the top of their support they are usually pinched out to prevent plants from becoming top heavy (RHS, 2015).

Plant spacings are about 15 to 30 x 90 cm for bush-type cultivars, and about 15 to 30 x 150 for pole- or trellis-supported production. About 4 months are required to complete the annual growth cycle. In Central America the crop may be interplanted, usually with maize.

The seeds of the plant can be used fresh or as dried beans. The pods are edible whole while they are young and not yet fibrous. The starchy roots are still eaten by Central American Indians. In some regions flowers are also consumed (Rubatzky, 1997).

During the cold season, the pods of the runner beans sold as "green beans", “snap beans” or ‘’string beans” in European markets usually come from Greece and northern Africa. The pods of runner beans can be identified by their big size and rougher surface.

Runner beans are a popular ingredient in Portuguese, Spanish, Greek, Austrian, and partially in German cuisine.

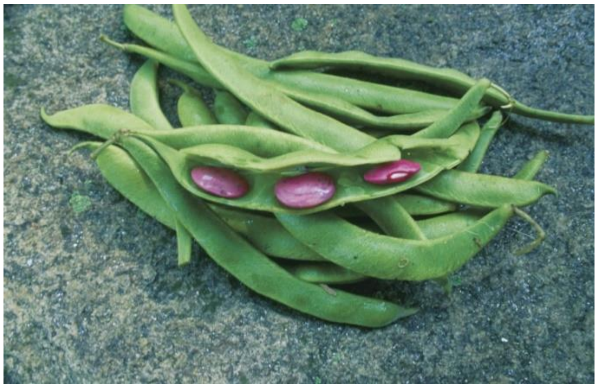

*Figure 1.5 - The runner beans pods*

### 1.2.2 - Runner beans diseases

For French, Navy and Runner beans the most common diseases are: Anthracnose (*Colletotrichum lindemuthianum*), Botrytis Pod Rot (*Botrytis cinerea*), Foot rots (*Fusarium solani*), Fusarium Wilt (*F. oxysporum f. sp. phaseoli*), Halo Blight (*Pseudomonas phaseolicola*), Rust (*Uromyces appendiculatus*), Sclerotinia Disease, Bean Yellow Mosaic Virus and Bean Common Mosaic Virus (House, 1982).

**Anthracnose** can lead to pronounced losses in beans. It is caused by the fungus *Colletotrichum lindemuthianum*. The infection is usually introduced by infected seeds and spread onto other plants with spores via rain drops. A heavy rainfall may spread the spores as far as 4.5 meters from the initial host plant (Pynenburg, 2011). The infected plant has reddish-brown spots on its pods, stems, veins, and under the surface of the leaves. The disease can be managed by checking the seeds for fungus, using fungicides on seeds, and burning plants in the end of season.

**Botrytis Pod Rot** is caused by the mold fungus *Botrytis cinerea*. Botrytis is a wide-spread pest of grapes, strawberries and some other plants. It is dangerous for runner beans mostly in the wet season, usually when the pods are touching the soil. The infected plant will have an identifiable a grey mold on its pods. To fight the disease the plants should be provided with a good drainage.

**Halo Blight** (*Pseudomonas phaseolicola*), causes water-soaked spots with yellow halo on affected leaves and pods. This seed-borne bacterial disease can result in severe epidemics in wet and cold summers. The infection spreads through wind-driven rain. Using infected seeds may result in plants with no growing point, so-called "snake heads". Use of colloidal copper or copper oxychloride may stop the spread of infection. It is recommended to check the seeds for halo blight at the seed testing stations.

**Rust** (*Uromyces appendiculatus*) is not a very common bean disease. The incidents of the infection are reported occasionally. The symptom is the brown or black pustules, with spores inside, appearing on the leaves. To control the disease it is recommended to burn or bury infected debris.

**Sclerotinia Disease** is caused by fungus *Sclerotinia sclerotiorum*. It is common in both outdoors and protected bean crops. The disease is favored by temperatures above 22°C. The fungus survives in soil, grows on debris, producing cup shaped bodies which give rise to airborne spores. The disease attacks the main stem of the bean which result in plat's wilting and collapse (House, 1982).

**Bean Yellow Mosaic Virus** and Bean Common Mosaic Virus is spread by **aphids** and rarely can be transmitted by seeds. The symptoms are greatly dependent on virus strain and on cultivar of the host plant.

**Bean Common Mosaic Virus** transmits in seeds and is spread by aphids. The main symptoms are leaves becoming crinkled and mottled with dark and pale green areas. To avoid the spread of the disease it is recommended to eliminate the infected plants and apply the means of aphid control.

## Soil-borne diseases

**Fusarium Wilt** (*F. oxysporum f. sp. phaseoli*) is a vascular fungal disease which can be very dangerous for runner beans. *Fusarium oxysporum* spreads by water splash and planting equipment on short distance, and by infected transplants and seed – on long distance. It infects plants by means of mycelia or by germinating spores penetrating the plant root tips. The mycelium penetrates in the xylem vessels and produces microconidia (asexual spores). Eventually the mycelium clogs the vascular vessels and causes the plant death. At first the leave edges of the infected plant turn yellowish-green, and then the whole leaf becomes dry. To control this disease it is recommended to promote drainage of the soil if it is too wet, perform crop rotation and use treated seeds (House, 1982). The typical symptoms of the disease are yellowing and eventual browning of the lower leaves and also brown staining of the xylem when exposed with a knife (Adams, 1984).

**Nematodes**

Nematodes, traditionally known as **eelworms**, are an important part of the soil microfauna, and are the most abundant and diverse animals in soil (there may be 30 million per square meter). While most nematodes are harmless or even beneficial (involved in decomposition processes), plant parasitic nematodes can directly impact the plant by feeding on its roots, and indirectly by affecting root architecture, interfering with water use efficiency, and facilitating infection by secondary pathogens, including bacteria, fungi and viruses (Costa et al., 2011). In a healthy soil, plant-parasitic nematodes are usually kept under control by fungi, bacteria and other nematodes. However they sometimes build up in the soil to the point where the soil becomes "sick." Plants growing in such soil show signs of nutrient deficiency because of serious root damage." (SmartGardenerInc., 2014)

Jones et al. have studied the economic effects of different pathogenic nematodes and published the list of the top 10 most pathogenic plant-parasitic nematodes: "(1) root-knot nematodes (*Meloidogyne* spp.); (2) cyst nematodes(*Heterodera* and *Globodera* spp.); (3) root lesion nematodes(*Pratylenchus* spp.); (4) the burrowing nematode *Radopholus similis*; (5) *Ditylenchus dipsaci*; (6) the pine wilt nematode *Bursaphelenchus xylophilus*; (7) the reniform nematode *Rotylenchulus reniformis*; (8) the needle nematode *Xiphinema index* (the only virus vector nematode to make the list); (9) the false root-knot nematode *Nacobbus aberrans*; and (10) *Aphelenchoides besseyi*." (Jones et al, 2013).

**Root Knot Nematodes** (*Meloidogyne* sp.) are obligate parasites of the roots of wide range of plant species that are very common in soil. The disease can be lethal for young plants and reduces yields in older ones. Nematodes cause an estimated 5% of the world yield loss (Sasser, 1985), but some infested fields can be abandoned as they are notoriously difficult to control (Nicol et al., 2010). The nematode *M. incognita* is probably the most damaging pathogen in the world (David, 2001).

Nematode species can be found in different climates from frozen soils to rainforests and remote islands (Sasser, 1985). *M. incognita*, which is one of the harmful species of nematodes, can survive only in places with mild winter, with average January temperature -1.1 °C or above. Like all nematodes, root-knot nematodes depend on soil moisture and live in water films in soil. Eggs and even the infective larvae, a resistant or dauer stage, can die in dry soil. To survive they need enough soil water to keep soil humidity at near 100% humidity (Taylor, 1978). In farms with sandy well-drained soil, these nematodes have been reportedly more problematic (Hagedorn, 1986).

There are approximately 100 species of root-knot nematodes, and of these only four have been given worldwide importance: *M. javanica*, *M. incognita*, *M. arenaria* and *M. hapla*. The root knot nematodes are usually no bigger than 0.5 mm in length and 0.015 mm in width and are too small to be seen with naked eye. They can be difficult to identify, and an analysis of their morphology will often need to be complemented by a biochemical or molecular analysis. As many, yet not all, species of root-knot nematodes are polyphagous, it is key to determine which species of root knot nematodes infects the crop, to plan the crop rotation (Queensland, 2015).

Root-knot nematodes do not produce any specific symptoms in the part of the plant above the ground, but show symptoms or root failure. Affected plants may look weak and often show symptoms of wilting or chlorosis (yellowing). Below ground, root-knot nematodes cause quite distinctive symptoms, like lumps, galls from 1 to 10 mm or more in diameter, all over the roots. In severe cases roots may rot away (Queensland, 2015).

Root-knot nematodes spend most of their life cycle inside plant roots and are very difficult to control. There are a few groups of methods to fight nematodes: crop rotation, biological control, chemical control, resistant cultivars, and solarization.

**Crop rotation** is helpful against many pests and diseases. To effectively exterminate nematodes it is good to rotate vegetable with grain cultures, but this also depends on the root-knot nematode species present (Hagedorn, 1986).

**Biological control** of nematodes is introducing their natural enemies into the field. For example *Pasteuria penetrans* – bacteria, that is an obligate parasite of root knot nematodes (Charles, 2005). Also various trapping fungi, *Paecilomyces lilacinus, Pochonia chlamydosporia, Hirsutella* spp., some antagonistic hizosphere bacteria, and endophytic fungi - non-pathogenic root-infecting fungi and mycorrhizae, can be used to fight nematodes (Kerry, 1997). For biological control a **trap crop** also can be used. This crop is planted near the main crop at the important stage of the pest life cycle, ie, when second stage larvae are moving in the soil. The trap crop attracts this infective stage that enters its roots and is then removed before they can multiply and move to the main crop (Wesemael, 2011).

**Chemical control** consists of the application of pesticides to kill nematodes. The most popular pesticides for this purpose are various Organophosphates and Carbamates in granular form. Some fumigants, such as chloropicrin and ethylene dibromine now are forbidden to use (Gowen, 1997), and it is estimated that many of the currently used nematicides will be banned in the next few years. The most efficient nematicide was also methyl bromide, which as described above, has already been banned in Europe.

There are some **cultivars resistant** against root-knot nematodes. However, nematodes can often overcome the resistance (Castagnone, 2014). Also, depending on environmental conditions, resistant plants may become susceptible (Verdejo-Lucas, 2013). Besides this, the cultivar might be resistant against one type of nematodes and at the same time susceptible towards other types of nematodes (Wesemael, 2011). Cultivars high resistance against nematodes and/or insects are rare among beans (Singh, 2010).

**Soil Solarization** is a method to control soilborne diseases, which uses sun heat to produce pronounced cycles of high-low temperatures and kill or attenuate the pathogens. The heating is achieved by covering the soil with plastic for 4 to 6 weeks during a hot period of the year. The top 15 cm of the soil will heat up to as high as 60°C, depending on the location. The plastic allows the heat from sun to stay in the soil. This can kill pathogens, such as nematodes, for 30 – 46 cm in depth, whilst providing conditions for the increase in populations of beneficial organisms (Elmore, 1997).

**Deep plowing** also has can help to exterminate nematodes, albeit with limited success (Hagedorn, 1986).

### 1.2.3 - Grafting of Runner beans

According to the available information, grafting of runner beans can be used to control soil borne diseases, caused by *Fusarium* spp. and *Meloidogyne* spp. in greenhouse crops. However it can cause negative effect on crop growth and development on all grafted, compared to ungrafted plants (Mourão, 2014). Also, it was shown by Mullin and Abawi that the resistance of bean plants against nematodes can be contributed solely by the root tissues, ie, the grafted plant has the level of resistance conferred by the rootstock. The tested grafted plants with a susceptible rootstock were susceptible towards nematodes, independently of the scion. In the same way, the resistant rootstock provided resistance for the plant, independently of the scion cultivar (Mullin, 1991).

In other studies, an increase in yield was achieved by grafting runner beans as rootstocks, and other *Phaseolus* as scions. Four genotypes of *Phaseolus vulgaris* and one genotype of *P. coccineus* were used as rootstocks. Two genotypes of *P. vulgaris*, and one each of *P. acutifolius* and *P. angustissimus*, and an interspecific hybrid of *P. acutifolius x P. angustissiumus* were used as scions. Grafting resulted in 91% and 66% higher mean seed yield per plant compared to ungrafted control and rooted cutting treatments, respectively.

Also the common **bean genotype ICA Pijao** was recommended as the best rootstock among the tested rootstocks: *P. coccineus* - Runner bean, *P. vulgaris* - Black bean ICA Pijao, *P. vulgaris* - Pinto bean, *P. vulgaris* - Brown bean, *P. vulgaris* - Pinto bean 1533-15 (Gurusamy, 2010).

According to Rodrigues, a grafted green bean plant costs € 0.50, while a conventional one only € 0.08. However the grafted ones are more vigorous and need less fertilizer due to the powerful root system, can be resistant to *Fusarium* spp., increase yield and production period. The first trials with grafted plants were held in summer of 2008 and produced exciting results, with the authors estimating that 80% of the green beans production in Portugal will be produced using grafting (Rodrigues, 2010).

### 1.2.4 - The fruit quality of green beans

Green beans should be **harvested** when they are in the rapid development, typically 8-10 days after flowering. To be harvested the pods must be bright color and fleshy, with small green seeds inside. If harvested too late, the pods lose flexibility and become pale green or yellow. The beans should be cooled down as soon as possible after harvesting. Otherwise they will lose water. After the pods lose 5% of their mass they become noticeable wilted. After 10-12% of weight loss the green beans become unmarketable (Cantwell, 2013). It is better to store the beans in a film wrap to maintain high relative humidity and prevent water loss. The **storage** temperature greatly affects the shelf life of green beans. It has been shown that the optimal temperature to store green beans regarding the shelf-life and fruit quality is 10°C. The average shelf life vary between different cultivars (Yagiz, 2010). Often runner beans are stored frozen and have to be thawed prior to commercialization. The thawing process is determinant for fruit quality as the pods lose sensory and nutritional value if thawed at room temperature in polyethylene packaging. The room temperature for thawing in insulation packaging can increase the thawing time for up to 190% and help to preserve the nutritional value, however the sensory value (taste, color) will still be greatly decreased. The recommended way to thaw green beans is at a temperature close to 0° C: this allows the preservation of nutritional and sensory value of the beans, whilst keeping them safe microbiologically (Martins, 2004).

The **fruit quality evaluation** usually includes the percent of dry mass fraction, the average length of the pods, defects including spots, browning and shriveling, the fruit color, the pod firmness. The fruit color can be estimated by naked eye, but for more precise measurements a colorimeter can be used. The pod firmness is normally evaluated manually, by slightly pressing the pod with fingers. The **laboratory studies** of the fruits usually include the following parameters: pH and titrable acidity, soluble solids content, ascorbic acid content, and chlorophyll content (Yagiz, 2010).

## 1.3 - Objectives of the thesis

Runner bean is a popular vegetable culture. It is often cultivated in green houses. To intensify its production, synthetic fertilizers along with pesticides are often used. However, using grafting can effectively and not expensive fight root parasites and increase the minerals uptake from the soil, due to development of stronger root system on the plant. This method has previously shown promising results for tomatoes.

The objective of this work is to test how grafting of runner beans cultivars Rajado and Oriente on the rootstocks P1: cv. Aintree (TozerSeeds), P2: cv. White Emergo (TS), and P3:cv. feijão de 7 anos (Portuguese landrace cv.) can affect the yield and resistance of the crop to soil borne disease, such as nematodes and Fusarium.

# 2. Materials and methods

Grafted runner beans (*Phaseolus coccineus*) were grown under unheated greenhouse conditions during spring/summer 2015, in greenhouse of Escola Superior Agrária, Politechnic Institute of Viana do Castelo (ESA IPVC), located in Refóios do Lima, Portugal (43°38'19.39"N, 16°14'28.86"W) (Fig. 2.1).

*Figure 2.1 - Greenhouse of ESA IPVC*

The plants were grown in a Cambisol soil with sandy loam texture (Table 2.1). The field was divided in two squares. To see on which square each planting block is located please refer to figure 2.2.

*Table 2.1 - Experimental soil characteristics, samples taken on 13.02.2015*

| | pH $H_2O$ | EC (dS $m^{-1}$) | OM (g $kg^{-1}$) | $P_2O_5$ ER [a] (mg $kg^{-1}$) | $K_2O$ ER [a] | Ca | Mg |
|---|---|---|---|---|---|---|---|
| Squere 1 | 5.8 | 0,168 | 49 | 49 | 86 | 113 | 29 |
| Squere 2 | 5.9 | 0.136 | 45 | 51 | 80 | 24 | 51 |

(a) ER - Egner-Rhiem method

For this culture we used three different fertilizers. On February 18th, 21 days before planting, we applied organic fertilizer, made of **sheep and cow manure** mixed with corn husks and stored/composted in piles for 5-6 months, at rate **16 t per hectare** (Fig. 2.3). After this, a commercial organic fertilizer **Organihum Nitro-Plus** was applied. This product consists of amino acids obtained from enzymatic hydrolysis of vegetable matter. It was applied through irrigation system for one watering, at concentration 150 ml/hl on 1.04.2015, and at 200 ml/hl on 8.04.2015, 24.04.2015, 30.04.2015, 8.05.2015, and 5.05./2015. A conventional fertilizer **Nitromagnesium** was applied on 1.06.2015 at rate 5.18 kg/ha. The fertilizer is a homogenous mixture of $NH_4NO_3$, $CaCO_3$ and $MgCO_3$. It contains 27% of Nitrogen, 3.5% of CaO and 3.5% MgO.

The soil was covered with plastic film. The **irrigation** was performed by a drip system, with drippers spaced at 0.30 m with 5.42 $l*h^{-1}$ flow rate (Table 2.2). The total use of water for the experimental plants was 3544.68 l = 59.078 l * 30 blocks * 2planting sites

*Table 2.2 - Irrigation system work regime*

| **Dates** | | **Duration, days** | **Irrigation, min/day** | **Per one hole** | | |
|---|---|---|---|---|---|---|
| **From** | **To** | | | **Flow rate, ml/min** | **Water per day,ml/day** | **Water total, ml** |
| 11-03-2015 | 22-03-2015 | 12 | 2 | 90.3 | *180.7* | 2 168 |
| 23-03-2015 | 19-04-2015 | 28 | 4 | 90.3 | *361.3* | 10 117 |
| 20-04-2015 | 02-07-2015 | 74 | 7 | 90.3 | *632.3* | 46 793 |
| | | **114** | | | | **59 078** |

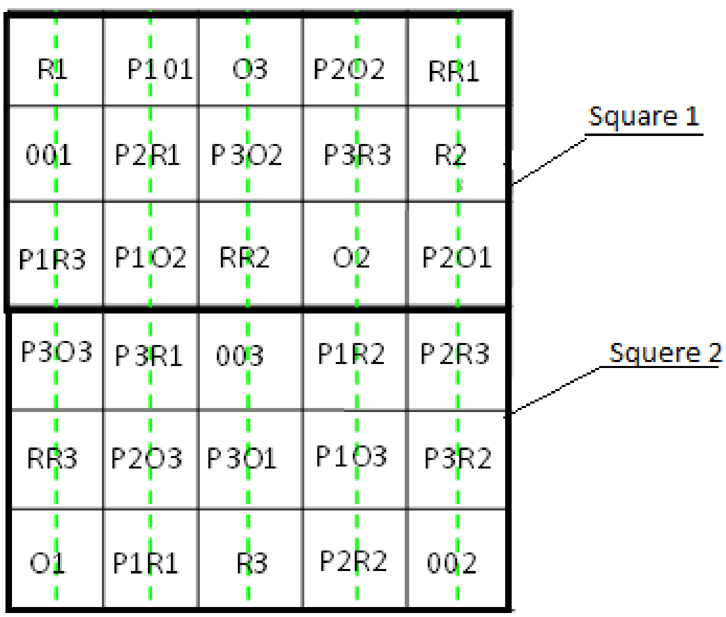


*Figure 2.2 - The areas for soil samples collection*

*Figure 2.3 - Fertilization*

A randomized block design experiment with **three repetitions** and **ten treatments** was carried out to evaluate crop yield and quality.

Each one of **thirty blocks** had 7 **planting sites**. For the experiment we used only the two plants in the middle of each block, called the test plants. The other four plants on the sides of the tested plants were used as "guardians" (Fig. 2.4).

| | | | | | | |
|---|---|---|---|---|---|---|
| G | G | **T** | **T** | G | G | X |

G – Guardian plants
**T – Tested plants**
X – Empty spot
*Figure 2.4 - The planting sites in a block*

As the scions we used bean cultivars O:Oriente and R:Rajado. As the rootstocks we used: P1: cv. Aintree (TozerSeeds), P2: cv. White Emergo (TS) and P3:cv. feijão de 7 anos (Portuguese landrace cv.). Also, for control experiment, we used self-grafted plants: OO and RR, and undrafted plants: R and O (Table 2.3).

The plants grafted on the rootstocks **P1, P2 or P3** originally had **2 stems** per plant. So they were planted one plant per one planting site. The **self-grafted** and **ungrafted** plants originally had **one stem** per plant, and they were planted two plants per one planting site (Fig. 2.6).

The plants were kindly provided by Dr. Rui Gilberto Calico, th manager at Viveiros Novos company, which is located in Povoa do Varzim (Fig.2.5).

*Figure 2.5 - The plant treatments used in the experiment*

*Figure 2.6 - The plant treatments used in the experiment*

*Table 2.3 - The plant treatments used*

| # | Treatments | Code | Nº of plants |
|---|---|---|---|
| 1 | Grafted P1 x O | P1O | 18 |
| 2 | Grafted P1 x R | P1R | 18 |
| 3 | Grafted P2 x O | P2O | 18 |
| 4 | Grafted P2 x R | P2R | 18 |

| | | | |
|---|---|---|---|
| 5 | Grafted P3 x O | P3O | 18 |
| 6 | Grafted P3 x R | P3R | 18 |
| 7 | Grafted O x O | OO | 36 |
| 8 | Grafted R x R | RR | 36 |
| 9 | Ungrafted O | O | 36 |
| 10 | Ungrafted R | R | 36 |

**O: Oriente** **P1: cv. Aintree (TozerSeeds)**

**R: Rajado** **P2: cv. White Emergo (TS)**

**P3:cv. feijão de 7 anos (Portuguese landrace cv.)**

The beans were gown at a stem spacing of 0.3 m in the line and 2 m between lines, in a plant density of 0.334 and 0.667 plants per $m^2$ respectively for the 1 and 2-stemmed plants (Fig. 2.7).

The training system was 2 m high and made of a two nylon strips per a planting site. After reaching the top of the training system the plants were pinched.

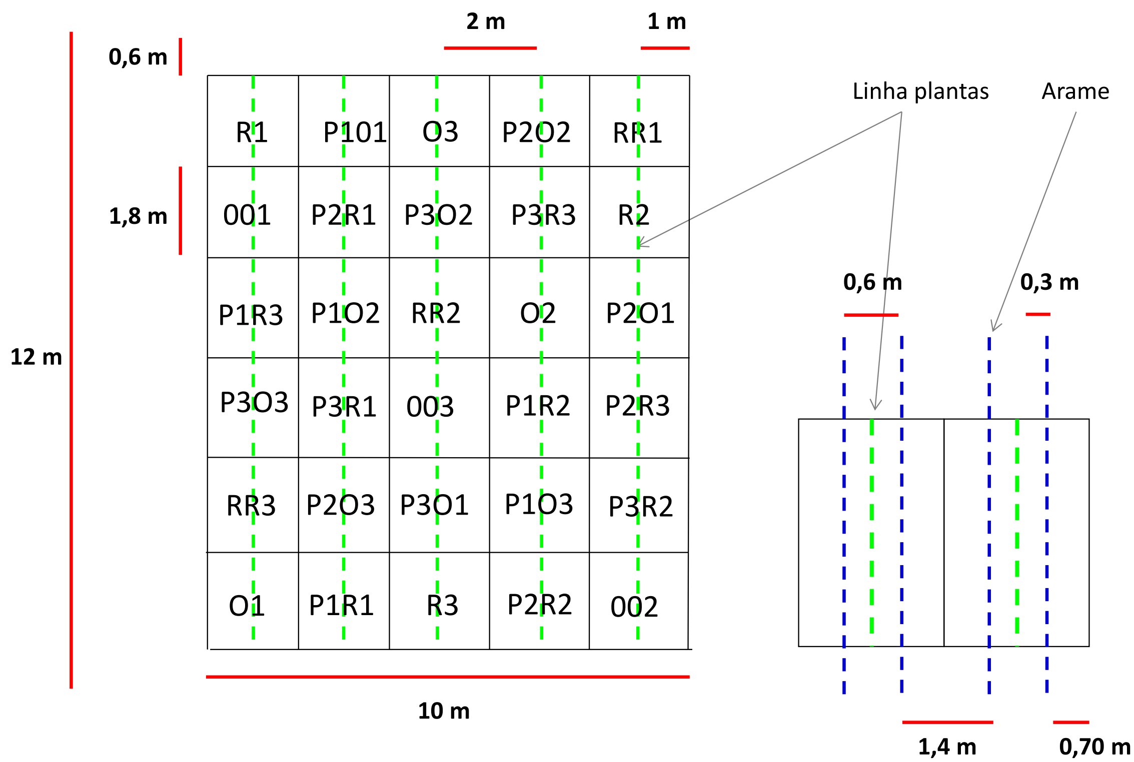


*Figure 2.7 - The planting scheme*

Various plant protection products were applied (Table 2.4).

*Table 2.4 - Plant protection applied*

| ***Pest/disease*** | | ***Product's commercial name*** | ***Active substance*** | ***Dose*** | ***Date*** |
|---|---|---|---|---|---|
| **Common name** | **Scientific name** | | | | |
| Black legume aphid | *Aphis craccivora* | - | Nettle extract | 1Kg/10 l of water | 13.05.2015 |
| Fusarium (Fig. 2.8) | *Fusarium oxysporum and Fusarium solani* | Previcur | **Fosetyl** sodium - 310 g/l or 27,68% m/m and **propamocarb** hydrochlorite - 530 g/l or 47,32% m/m | 150 ml/ hl | 3.06.2015 and 17.06.2015 |
| Thrips | *Thysanoptera* | Rufaste | 75 g / l or 7.02% m/m **acrinathrin** | 80 ml/ hl | 3.06.2015 |
| Silverleaf whitefly | *Bemisia argentifolii* | Fastac | 100 g / l or 10.95% m/m **alpha-cypermethrin** | 30 ml/hl | 29.06.2015 |

*Figure 2.8 - Roots infected by Fusarium solani*

The temperature and relative humidity of the air inside the greenhouse were measured and recorded by the thermohygrograph (Fig.2.9). The temperature and relative humidity values were recorded during the period from 22.04.2015 till 02.07.2015 (Fig. 2.10 and 2.11).

*Figure 2.9 - The thermohygrograph at the greenhouse*

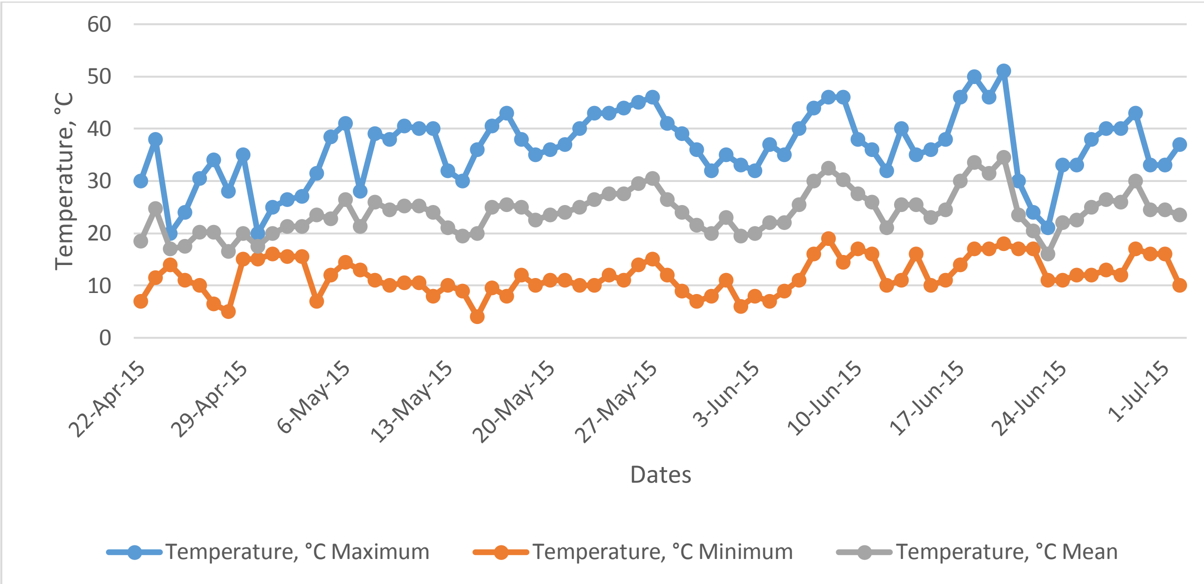


*Figure 2.10 - Temperature in greenhouse 22.04.2015 – 2.07.2015*

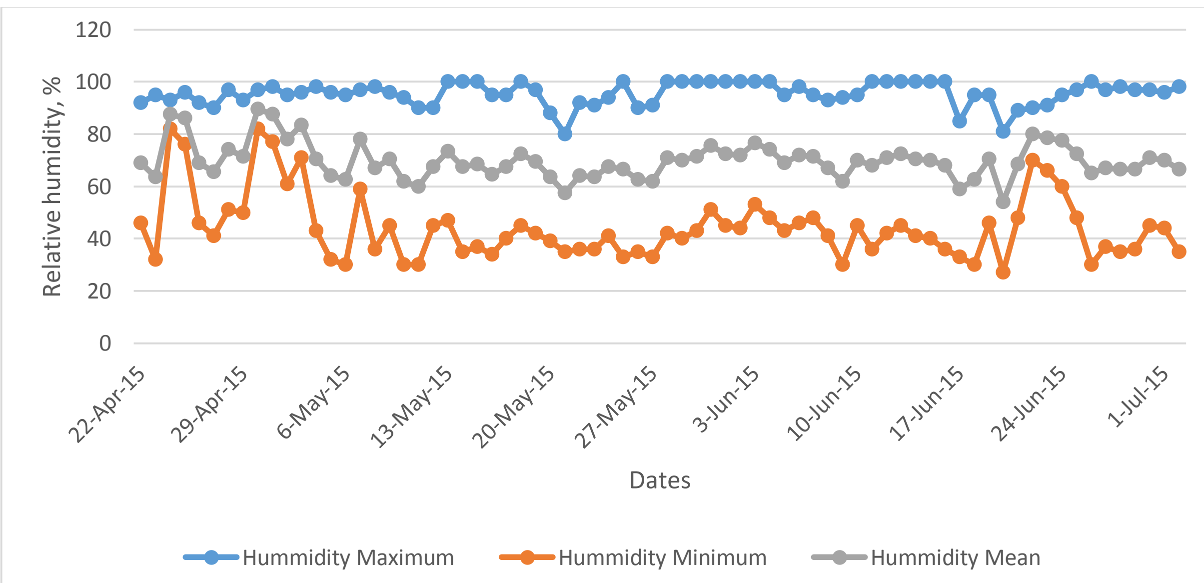


*Figure 2.11 - Relative humidity in greenhouse 22.04.2015 – 2.07.2015*

The pollination was done by bees, naturally visiting the greenhouse through the ventilation. Weeding was done by hands, no herbicides were applied.

The bean plants were **planted** in the greenhouse on **March 11$^{th}$**. The first **harvest** took place on **May 6th** (56 days after planting) and the last harvest on July 2nd (114 days after planting). During these 57 days two plants for each treatment repetition were **harvested two times per week** (16 harvests). The number and length of the bean pods, the number of pods with minor defects and number of pods with serious defects, as well as fresh weight were recorded for each harvest. Dry weights were evaluated for four harvests during the harvesting period. Fruit dry matter content was determined after drying the fruit in a ventilated oven at 70°C for 48 hours.

Analysis of variance (ANOVA) was performed by the general linear model SPSS procedure using SPSS 17.0 for Windows (SPSS Inc.) and compost treatments were compared by the least significant difference (LSD) test. A probability level of $\alpha=0.05$ was applied to determine statistical significance.

## 3. Results

### 3.1 - Dead plants

The runner bean crop was at plant density 3.3 stems $m^{-2}$ (12 stems/3.6 $m^2$), meaning that the number of normal and self-grafted plants with one stem per plant, was double (33000 plants $ha^{-1}$), the double-stemmed grafted plants (16667 plants $ha^{-1}$). The number of plants per crop treatment throughout the field experiment was two for the grafted plants and four for the normal and self-grafted plants occupying the same area. Thus, the evaluation of dead stems considered the four stems in observation.

None of the plants in treatments self-grafted cv. Rajado (RR), and cv. Oriente grafted onto rootstock P3 (P3O) died. The first crop treatment where plants started to die 71 days after planting (DAP) was the cv. Oriente grafted onto rootstock P2 (P2O), followed by the same cv. grafted onto rootstock P1 (P1O) and cv. Rajado grafted onto rootstock P2 (P2R) 78 DAP; the cv. Rajado grafted onto rootstock P1 (P1R) and self-grafted cv. Oriente (OO) 82 DAP and, finally, cv. Rajado grafted onto rootstock P3 (P3R) 85 DAP. Only P1O e P2R had more dead stems after the first ones, respectively at 82 e 89 DAP (Fig. 3.1).

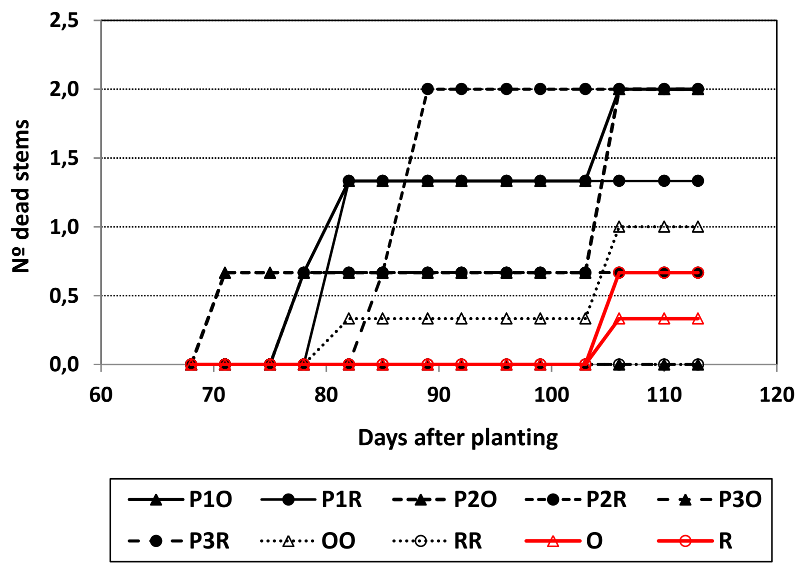


*Figure 3.1 - Mean number of dead stems (out of 4) from 68 days after planting, for the runner bean plants of cv. Oriente and cv. Rajado, ungrafted (O, R), self-grafted (OO, RR) and grafted onto rootstocks P1, P2 and P3.*

The final number of dead stems was significantly higher for the rootstocks P2 (2.0 dead stems) compared to the rootstocks P3 (0.3 dead stems) and was similar to the other crop treatments (Fig. 3.2 a). Both cultivars Oriente and Rajado had similar final number of dead stems (Fig. 3.2 b).

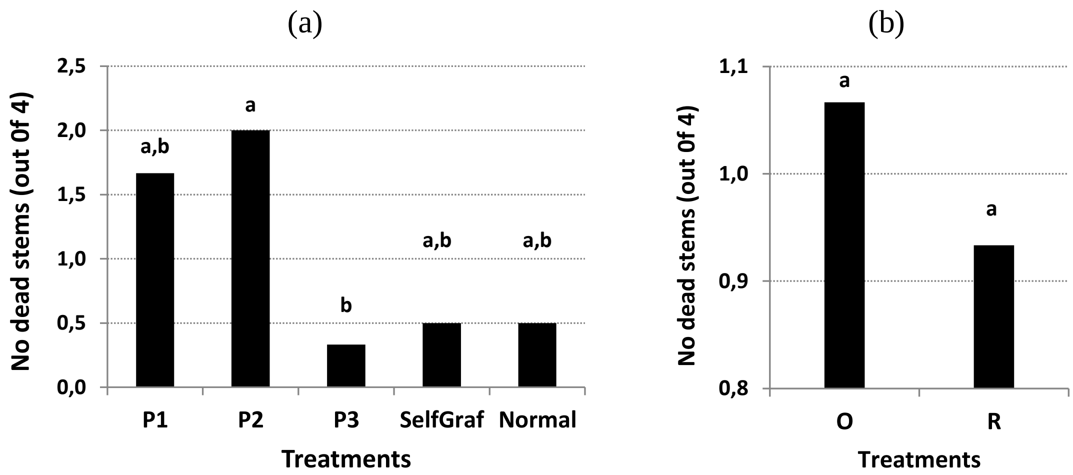


*Figure 3.2 - Final number of dead stems for (a) the two runner bean cultivars grafted onto rootstocks P1, P2 and P3, self-grafted and ungrafted (normal plants) and for (b) all crop treatments of the cv. Oriente and cv. Rajado. Different letters above bars mean significant differences between crop treatments ($p < 0.05$).*

## 3.2 - Crop development and growth

The first flower appeared earlier in plants grafted onto the P3 rootstock and the ungrafted crop treatments (mean 35.9 DAP) compared to P1 and self-grafted (mean 42.2 DAP) and were similar to P2. Consequently the first pod was observed approximately 6 days after the first flower, earlier for the P3, ungrafted as well as P2 crop treatments (mean 42 DAP), compared to P1 and self-grafted (mean 47.9 DAP), (Fig. 3.3 a). The cv. Oriente presented the first flower three days earlier than cv. Rajado, although the first pod appeared at the same time for both cultivars (mean of 44.4 DAP) (Fig. 3.3 b).

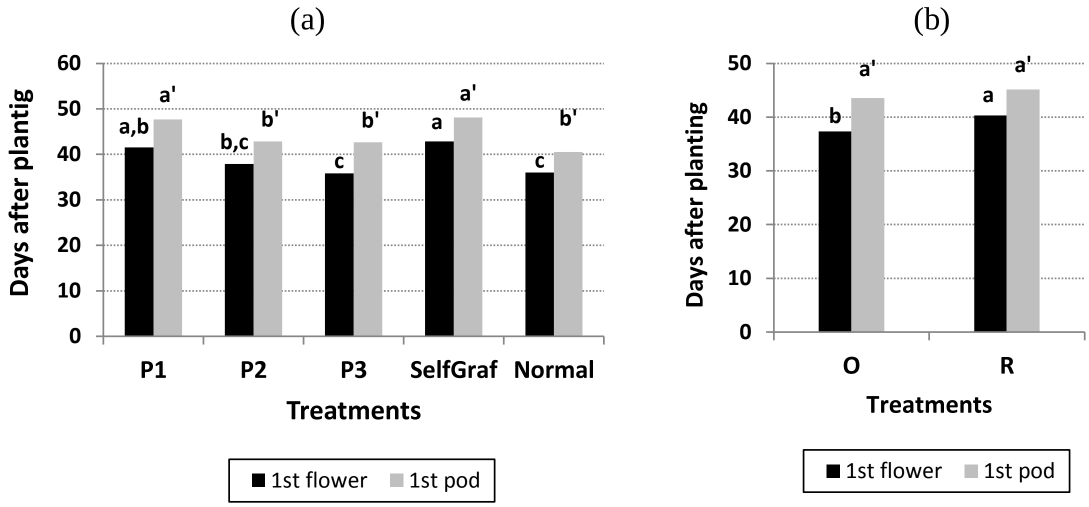


*Figure 3.3 - Days after planting of the first flower and first pod appearance for (a) the two runner bean cultivars grafted onto rootstocks P1, P2 and P3, self-grafted and ungrafted (normal plants) and for (b) all crop treatments of the cv. Oriente and of the cv. Rajado. Different letters above bars mean significant differences between crop treatments ($p < 0.05$).*

The interaction between the rootstock crop treatments (P1, P2, P3, self-grafted and ungrafted) and the two runner bean cultivars (Oriente and Rajado) was not significant for all crop measured parameters.

The accumulated number of pods throughout the growing period, represented in Figure 3.4, showed that the runner bean plants grafted onto rootstock P3 produced more pods than the other crop treatments from 89 DAP onwards. In fact, the total number of pods ($m^{-2}$) produced was significantly higher for this crop treatment ($p<0.05$) compared to the others (Fig. 3.5), and the two cultivars produced similar total number of pods (Fig. 3.11 b).

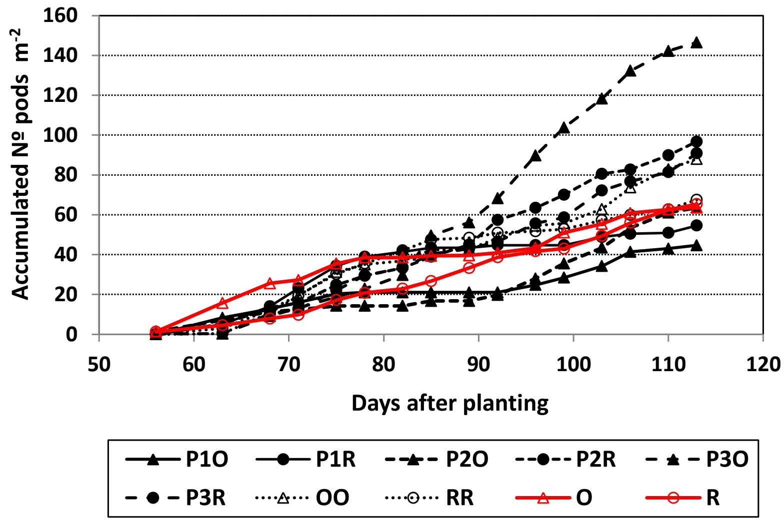


*Figure 3.4 - Accumulated number of pods throughout the growing period for the runner bean plants of cv. Oriente and cv. Rajado, ungrafted (O, R), self-grafted (OO, RR) and grafted onto rootstocks P1, P2 and P3.*

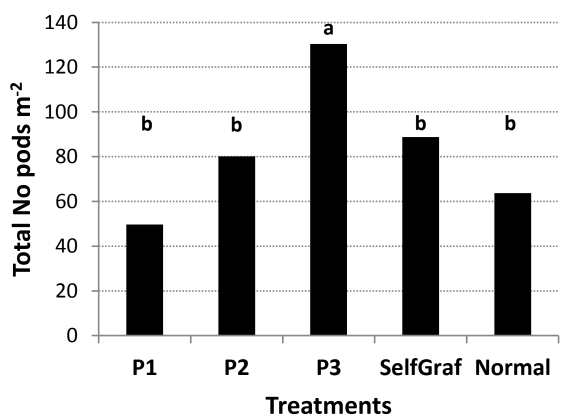


*Figure 3.5 - Total number of pods ($m^{-2}$) for the two runner bean cultivars grafted onto rootstocks P1, P2 and P3, self-grafted and ungrafted (normal plants). Different letters above bars mean significant differences between crop treatments ($p < 0.05$).*

The accumulated fresh weight of pods throughout the growing period, showed a similar pattern to the number of pods (Fig. 3.6), and the yield for the grafted plants onto rootstock P3 (1.57 kg $m^{-2}$) was higher compared to the P1, P2 and ungrafted plants, with no significant differences with the self-grafted plants (Fig. 3.7).

Although the interaction between rootstock and cultivar treatments were not significant, the analysis of variance of yield data for each cultivar showed that no significant differences were found between crop treatments for cv. Rajada, although P2 and P3 rootstocks doubled crop yield (1.0 kg $m^{-2}$) compared to the other three crop treatments (mean of 0.5 kg $m^{-2}$) (Fig. 3.8). For the cv. Oriente the rootstock P3 induced to a significant higher yield (2.1 kg $m^{-2}$) compared to ungrafted and grafted onto rootstocks P1 and P2 plants (mean of 0.8 kg m$^{-2}$), although yield of self-grafted plants were similar to all crop treatments (Fig. 3.8).

Yield of the cv. Oriente (1.2 kg m$^{-2}$) was higher ($p<0.05$) compared to the cv. Rajado (0.7 kg m$^{-2}$) (Fig. 3.12).

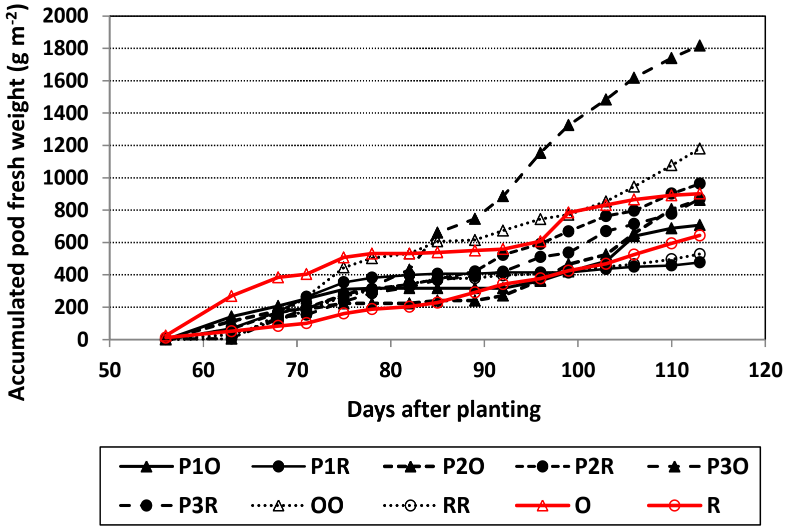


*Figure 3.6 - Accumulated pods fresh weight (g m-2) throughout the growing period for the runner bean plants of cv. Oriente and cv. Rajado, ungrafted (O, R), self-grafted (OO, RR) and grafted onto rootstocks P1, P2 and P3.*

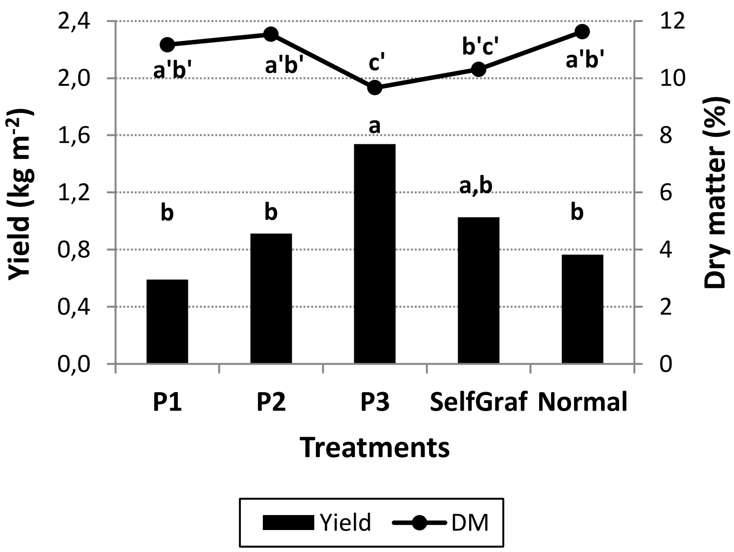


*Figure 3.7 - Crop yield (kg m-2) and pod dry matter (%) for the two runner bean cultivars grafted onto rootstocks P1, P2 and P3, self-grafted and ungrafted (normal plants). Different letters above bars mean significant differences between crop treatments (p <0.05).*

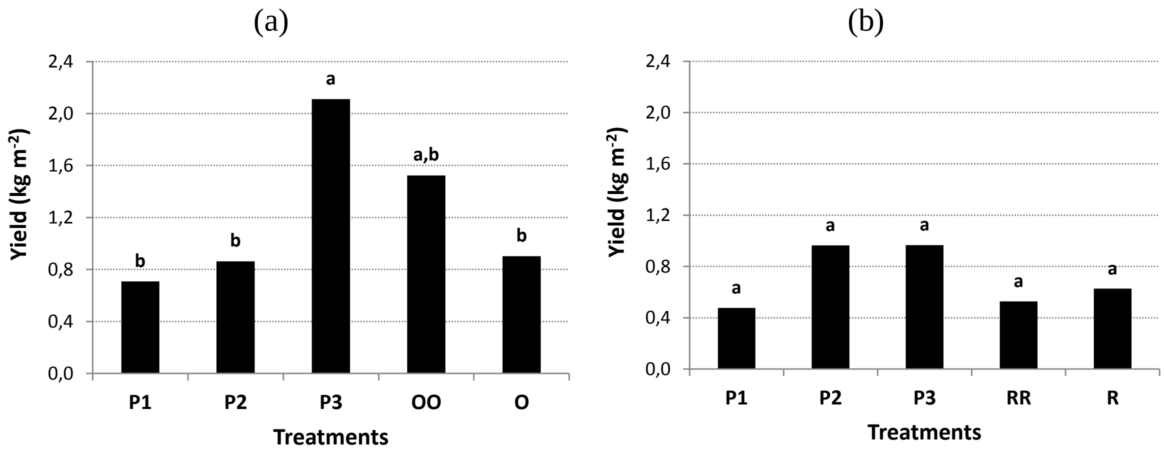


*Figure 3.8 - Crop yield (kg m-2) for the (a) cv. Oriente and (b) cv. Rajado, grafted onto rootstocks P1, P2 and P3, self-grafted and ungrafted (normal plants). Different letters above bars mean significant differences between crop treatments (p <0.05).*

From 75 DAP all crops suffered from lack of nutrients, mainly nitrogen, which was applied at 82 DAP (1 June) leading to an increase of plant development and growth, perceived approximately 10 days after (Fig. 3.6). In addition, at about the same period symptoms of the diseases caused by *Fusarium oxysporum* and *Fusarium solani*, were detected, and therefore a fungicide was applied twice, at 84 and 98 DAP. The rootstock P3 seemed to be the one that withstood better these abiotic and biotic stresses, being more tolerant to them.

## 3.3 - Dry matter content of the pods

Pod dry matter ranged between 9.0% and 13.1% throughout the growing period (Fig. 3.9) and the mean pod dry matter was significantly lower ($p<0.05$) in the P3 (9.7%) than in the P1, P2 and ungrafted crop treatments (mean 11.4%), with no significant differences compared to the self-grafted treatment (Fig. 3.7).

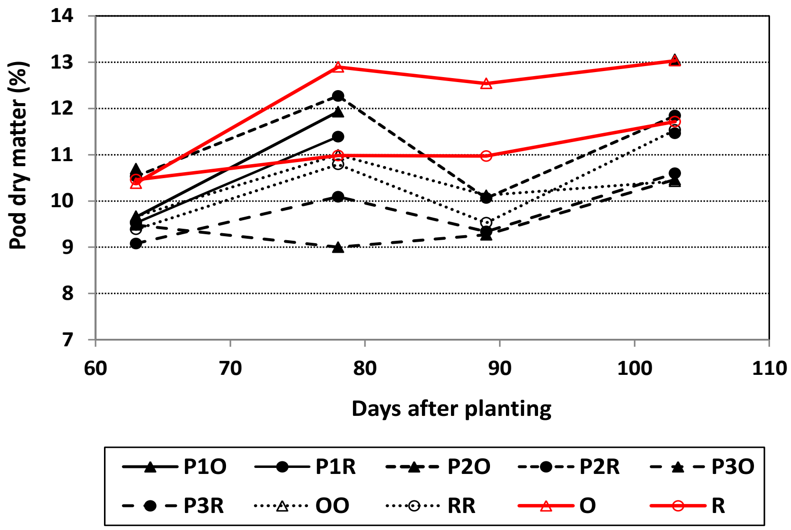


*Figure 3.9 - Pod dry matter (%) throughout the growing period for the runner bean plants of cv. Oriente and cv. Rajado, ungrafted (O, R), self-grafted (OO, RR) and grafted onto rootstocks P1, P2 and P3.*

## 3.4 - Pod length

The mean pod length throughout the growing period tends to diminish throughout the growing period for both runner bean cultivars (Fig.3.10). The higher pod length was found in the P3 (16.8 cm $pod^{-1}$), compared to P1, self-grafted and ungrafted crop treatments (mean of 14.9 cm $pod^{-1}$) and similar to the P2 (16.1 cm $pod^{-1}$), which was not significantly different compared to the other crop treatments (Fig. 3.11). The mean pod length of cv. Oriente was 17.0 cm $pod^{-1}$ and was higher ($p<0.05$) than the mean pod length of cv. Rajado (14.0 cm $pod^{-1}$) (Fig. 3.12 a).

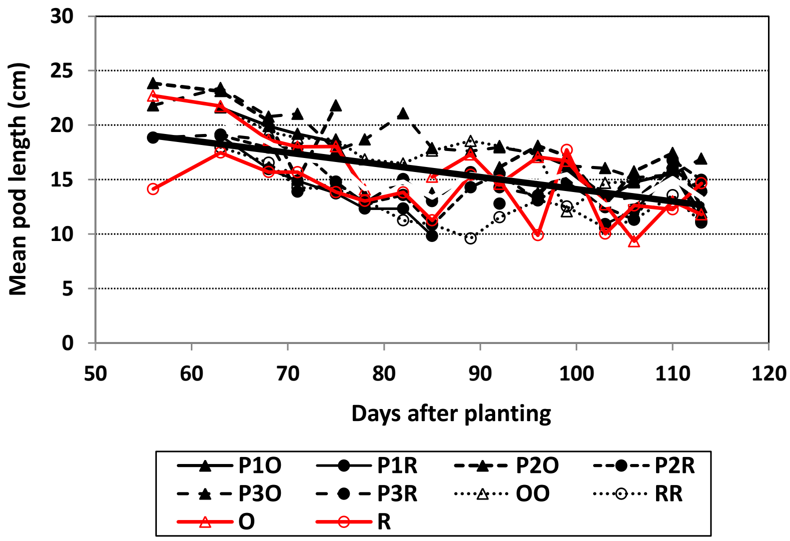


*Figure 3.10 - Mean pod length (cm pod-1) throughout the growing period for the runner bean plants of cv. Oriente and cv. Rajado, ungrafted (O, R), self-grafted (OO, RR) and grafted onto rootstocks P1, P2 and P3. The line is the linear model for the overall mean pod length in each harvest.*

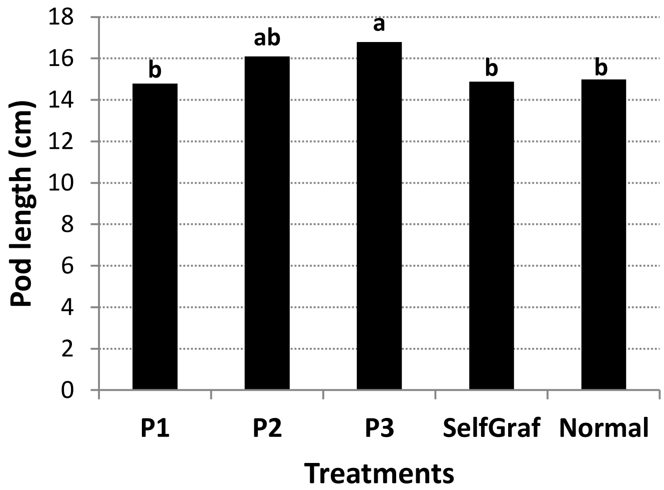


*Figure 3.11 - Mean pod length (cm pod-1) for the two runner bean cultivars grafted onto rootstocks P1, P2 and P3, self-grafted and ungrafted (normal plants). Different letters above bars mean significant differences between crop treatments ($p < 0.05$).*

Yield of the cv. Oriente was higher compared to the cv. Rajado mainly due to the longer pods as the total number of pods was similar (Fig. 3.12).

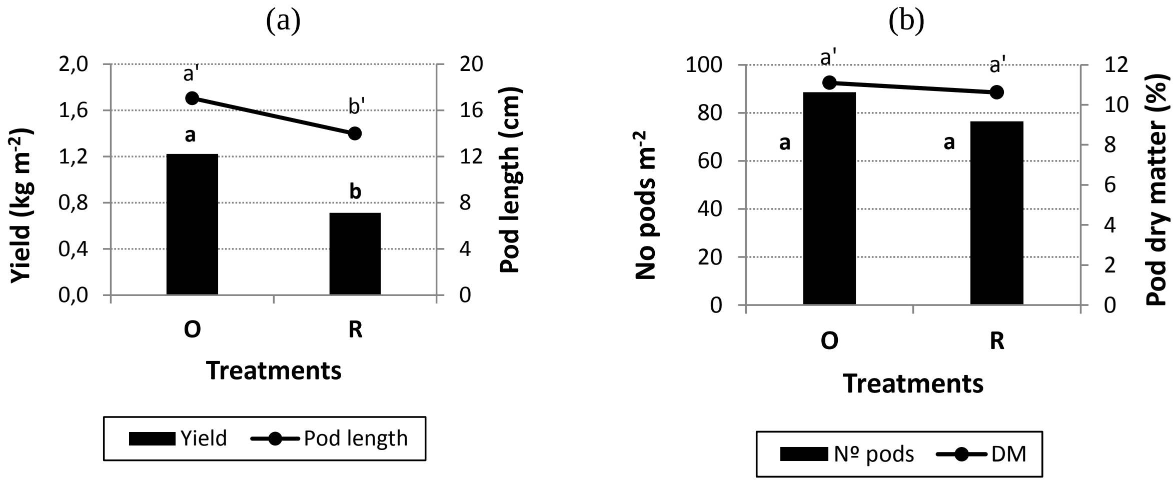


*Figure 3.12 - (a) Crop yield (kg $m^{-2}$) and mean pod length (cm $pod^{-1}$); (b) total number of pods ($m^{-2}$) and pod dry matter (%), for all crop treatments of the cv. Oriente and of the cv. Rajado. Different letters above bars mean significant differences between crop treatments ($p < 0.05$).*

## 3.5 - Pod defects

The pod defects considered were classified as minor when pods presented a little twist or bend, and as serious when pods were greatly bent or distorted and when disease symptoms were present. The minor defects were the main problem found in the pods and were present throughout the growing period (Fig. 3.13). The number of pods with serious defects (mean of 10.3 pods $m^{-2}$) and with disease symptoms (mean of 1.8 pods $m^{-2}$) were similar for all crop treatments and for the two runner bean cultivars (Fig. 3.14).

The minor defects were higher ($p<0.05$) in the P3 crop treatment (32.0 pods $m^{-2}$) compared to the other crop treatments (mean of 23.2 pods $m^{-2}$) (Fig. 3.14 a), but the percentage of these pods from the total number of pods were 24.6% for the P3 and was 33.9% for the other crop treatments.

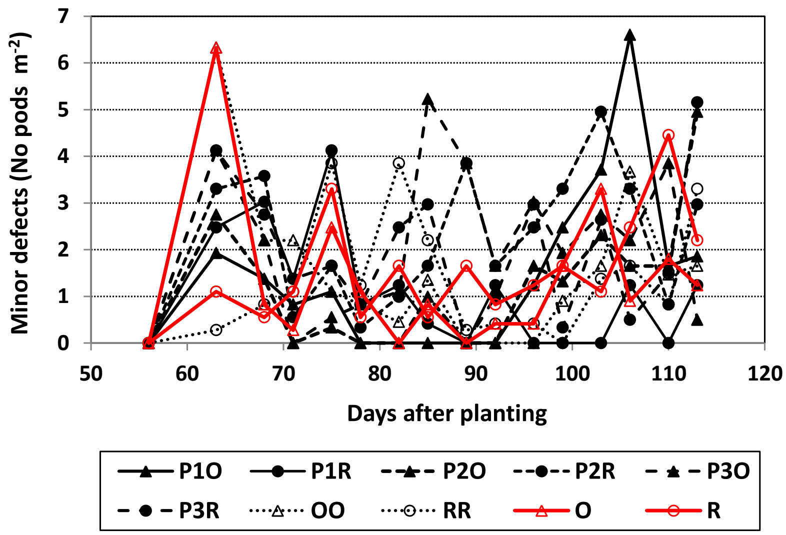


*Figure 3.13 - Minor pod defects (No of pods m$^{-2}$) throughout the growing period for the runner bean plants of cv. Oriente and cv. Rajado, ungrafted (O, R), self-grafted (OO, RR) and grafted onto rootstocks P1, P2 and P3.*

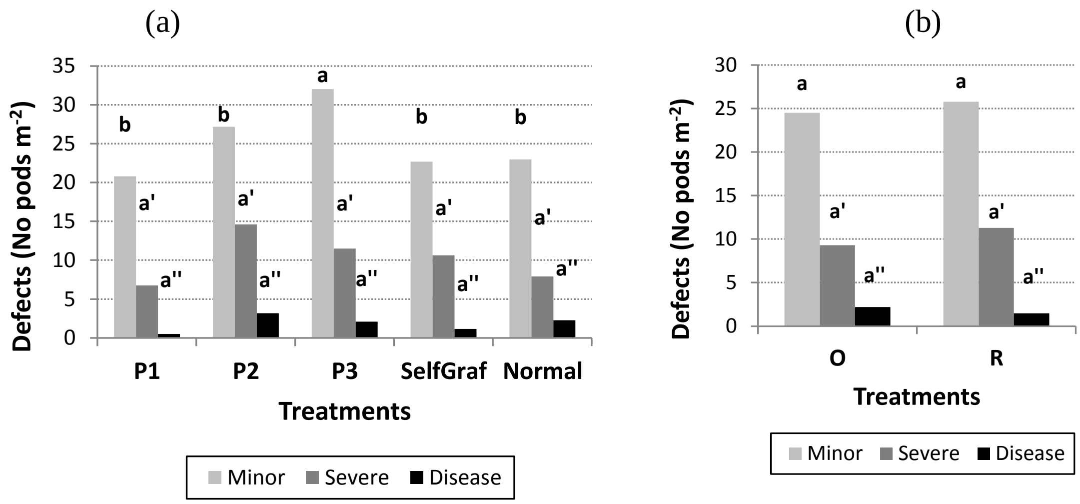


*Figure 3.14 - Pod defects (minor, severe and with disease symptoms) (No of pods m-2), for (a) the two runner bean cultivars grafted onto rootstocks P1, P2 and P3, self-grafted and ungrafted (normal plants) and for (b) all crop treatments of the cv. Oriente and of the cv. Rajado. Different letters above bars mean significant differences between crop treatments ($p < 0.05$).*

# 4. Discussion and conclusions

## 4.1 - Crop development and growth

The main objective of the present field experiment was to investigate the effect of three rootstocks for two commercial runner bean cultivars and, for this purpose, the rootstock P3 seemed to perform better than the rootstocks P1 and P2, at least for the cv. Oriente.

The plants from cv. Oriente grafted onto this rootstock P3 did not die and for cv. Rajado the plants grafted onto P3 were the last grafted crop treatment showing dead stems. The crop development was similar between the rootstock P3 and ungrafted plants as well as rootstock P2. The first flower appeared at the same time and earlier when compared to P1 and self-grafted crop treatments, although the fruit set was at the same approximate time.

The nitrogen deficiency due to poor crop management and the presence of soilborne diseases were abiotic and biotic stresses that the rootstock P3 seemed to withstand better than the other rootstocks, at least for cv. Oriente. Probably a more developed and deeper root system of P3 allowed the uptake of more nutrients and a higher tolerance to *Fusarium* spp. could explain the better performance.

Rootstock P3 produced a higher total number of pods and higher yield when compared to the P1, P2 and ungrafted plants, with no significant differences with the self-grafted plants. However, these results were due to the results obtained by cv. Oriente, as yield data analysis for each cultivar showed that no significant differences were found between crop treatments for cv. Rajado, although P2 and P3 crop treatments doubled crop yield (1.0 kg $m^{-2}$) compared to the other crop treatments (0.5 kg $m^{-2}$). On the other hand, for cv. Oriente the rootstock P3 induced to a significantly higher yield (2.1 kg $m^{-2}$) compared to ungrafted and grafted onto rootstocks P1 and P2 plants (mean of 0.8 kg $m^{-2}$), although yield of self-grafted plants were similar to all crop treatments for this cultivar.

The interaction between the rootstock crop treatments (including the self-grafted and the ungrafted plants) and the two runner bean cultivars (Oriente and Rajado) was not significant for all measured crop parameters, meaning that the effect of grafting was not dependent on the crop cultivars.

Both cultivars, Oriente and Rajado, had similar responses for the final number of dead stems. The crop development was similar between them, as cv. Oriente presented the first flower three days earlier than cv. Rajado, but the first pod appeared approximately at the same time.

The overall mean yield of the cv. Oriente (1.2 kg $m^{-2}$) was higher ($p<0.05$) compared to the cv. Rajado (0.7 kg $m^{-2}$), mainly due to the longer pods as the total number of pods was similar.

## 4.2 - Crop quality

Pod dry matter followed the yield response; the higher yield corresponded to lower pod dry matter, which can be due to higher rate of pod growth.

The higher pod length was found in the P3 (16.8 cm $pod^{-1}$), compared to P1, self-grafted and ungrafted crop treatments (mean of 14.9 cm $pod^{-1}$) and similar to the P2 (16.1 cm $pod^{-1}$), which was not significantly different compared to the other crop treatments.

The mean pod length is cultivar dependent as it is a characteristic of each cultivar. Oriente has longer pods (mean of 17.0 cm $pod^{-1}$) than cv. Rajado (14.0 cm $pod^{-1}$) which is a standard traditional runner bean.

The minor defects were higher in the P3 compared to the other crop treatments but the percentage of these pods from the total number was lower, 24.6% for plants grafted onto this P3 rootstock, compared to the other crop treatments (33.9%). There were no differences between the two cultivars for the number of pods with different defect types.

In conclusion, grafting runner bean seems to be an appropriate strategy to increase crop tolerance to soilborne diseases caused by *Fusarium* spp. and nutrient uptake, mainly for higher yielded cultivars as cv. Oriente. For this cv. the rootstock P3 was recommended, while for cv. Rajado, further investigation should continue to evaluate the effects of rootstocks P2 and P3. Unlike rootstocks 1 (cv. Aintree) and 2 (cv. White Emergo Snowy), originally obtained from Tozerseeds, rootstock 3 (cv. Feijão de 7 anos) is a Portuguese, local, cultivar. It has not been selected, improved or produced *en masse*, but rather handed down between farmers for generations. Therefore, it cannot be considered a stabilized cultivar, and the observed differences between this rootstock and the commercially-available ones must be interpreted in light of this. This cultivar shows great potential for use as a runner bean rootstock in cultivation under the tested conditions. It is likely that, after appropriate selection, levels of stress tolerance and yield will be significantly higher and less variable as those observed in this trial. This is a promising output of the work undertaken, and more research needs to be done to stabilize the cultivar, assess the levels of resistance to soil-borne pathogens in controlled conditions, and evaluate the response of Feijão de 7 anos to various abiotic conditions, including temperature, salinity, water and nutrient stresses, all of which have become serious issues for agricultural systems in the last decades. This will form part of an overall strategy to contribute to the development of a more sustainable, ecologically-sound and socially-responsible agricultural food production.

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# Attachment 1. Statistical analysis of the results

## Statistical analysis of the data for the scion cultivar Oriente

**Tests of Between-Subjects Effects**

*** p>0.05 the differences between the treatments are not significant**
**p<=0.05 the treatments are significantly different**

| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | p* |
|---|---|---|---|---|---|---|
| Rootstock | Dead Stems | 10,267 | 4 | 2,567 | 1,158 | ,397 |
| | Dry Matter | 13,516 | 4 | 3,379 | 3,417 | ,065 |
| | Length of pods | 11,431 | 4 | 2,858 | 1,790 | ,224 |
| | N of Pods | 24518,511 | 4 | 6129,628 | 4,346 | ,037 |
| | Fresh Weight | 4424008,573 | 4 | 1106002,143 | 3,343 | ,069 |
| | Minor defects | 788,229 | 4 | 197,057 | 3,850 | ,050 |
| | Serious defects | 115,380 | 4 | 28,845 | 1,590 | ,267 |
| | Diseases | 4,757 | 4 | 1,189 | ,366 | ,827 |
| | Date of first flower | 88,167 | 4 | 22,042 | 2,504 | ,125 |
| | Date of first pod | 35,767 | 4 | 8,942 | ,621 | ,660 |
| Error | Dead Stems | 17,733 | 8 | 2,217 | | |
| | Dry Matter | 7,912 | 8 | ,989 | | |
| | Length of pods | 12,769 | 8 | 1,596 | | |
| | N of Pods | 11284,033 | 8 | 1410,504 | | |
| | Fresh Weight | 2646858,735 | 8 | 330857,342 | | |
| | Minor defects | 409,459 | 8 | 51,182 | | |
| | Serious defects | 145,108 | 8 | 18,139 | | |
| | Diseases | 26,003 | 8 | 3,250 | | |
| | Date of first flower | 70,433 | 8 | 8,804 | | |
| | Date of first pod | 115,133 | 8 | 14,392 | | |

a R Squared = ,387 (Adjusted R Squared = -,073)
b R Squared = ,698 (Adjusted R Squared = ,471)
c R Squared = ,495 (Adjusted R Squared = ,117)
d R Squared = ,711 (Adjusted R Squared = ,495)
e R Squared = ,671 (Adjusted R Squared = ,424)
f R Squared = ,690 (Adjusted R Squared = ,457)
g R Squared = ,668 (Adjusted R Squared = ,420)
h R Squared = ,231 (Adjusted R Squared = -,346)
i R Squared = ,557 (Adjusted R Squared = ,224)
j R Squared = ,280 (Adjusted R Squared = -,260)

**Pairwise Comparisons**

| Dependent Variable | (I) PortaEnx | (J) PortaEnx | Mean Difference (I-J) | Std. Error | Sig.(a) | 95% Confidence Interval for Difference(a) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Upper Bound | Lower Bound |
| Dead Stems | Normal | P1 | -1,667 | 1,216 | ,208 | -4,470 | 1,137 |
| | | P2 | -1,667 | 1,216 | ,208 | -4,470 | 1,137 |
| | | P3 | ,333 | 1,216 | ,791 | -2,470 | 3,137 |
| | | self | -,667 | 1,216 | ,598 | -3,470 | 2,137 |
| | P1 | Normal | 1,667 | 1,216 | ,208 | -1,137 | 4,470 |
| | | P2 | ,000 | 1,216 | 1,000 | -2,803 | 2,803 |
| | | P3 | 2,000 | 1,216 | ,139 | -,803 | 4,803 |
| | | self | 1,000 | 1,216 | ,435 | -1,803 | 3,803 |
| | P2 | Normal | 1,667 | 1,216 | ,208 | -1,137 | 4,470 |
| | | P1 | ,000 | 1,216 | 1,000 | -2,803 | 2,803 |
| | | P3 | 2,000 | 1,216 | ,139 | -,803 | 4,803 |
| | | self | 1,000 | 1,216 | ,435 | -1,803 | 3,803 |
| | P3 | Normal | -,333 | 1,216 | ,791 | -3,137 | 2,470 |
| | | P1 | -2,000 | 1,216 | ,139 | -4,803 | ,803 |
| | | P2 | -2,000 | 1,216 | ,139 | -4,803 | ,803 |
| | | self | -1,000 | 1,216 | ,435 | -3,803 | 1,803 |
| | self | Normal | ,667 | 1,216 | ,598 | -2,137 | 3,470 |
| | | P1 | -1,000 | 1,216 | ,435 | -3,803 | 1,803 |
| | | P2 | -1,000 | 1,216 | ,435 | -3,803 | 1,803 |
| | | P3 | 1,000 | 1,216 | ,435 | -1,803 | 3,803 |
| Dry Matter | Normal | P1 | ,700 | ,812 | ,414 | -1,172 | 2,572 |
| | | P2 | ,200 | ,812 | ,812 | -1,672 | 2,072 |
| | | P3 | 2,567(*) | ,812 | ,013 | ,694 | 4,439 |
| | | self | 1,567 | ,812 | ,090 | -,306 | 3,439 |
| | P1 | Normal | -,700 | ,812 | ,414 | -2,572 | 1,172 |
| | | P2 | -,500 | ,812 | ,555 | -2,372 | 1,372 |
| | | P3 | 1,867 | ,812 | ,051 | -,006 | 3,739 |
| | | self | ,867 | ,812 | ,317 | -1,006 | 2,739 |
| | P2 | Normal | -,200 | ,812 | ,812 | -2,072 | 1,672 |
| | | P1 | ,500 | ,812 | ,555 | -1,372 | 2,372 |
| | | P3 | 2,367(*) | ,812 | ,019 | ,494 | 4,239 |
| | | self | 1,367 | ,812 | ,131 | -,506 | 3,239 |
| | P3 | Normal | -2,567(*) | ,812 | ,013 | -4,439 | -,694 |
| | | P1 | -1,867 | ,812 | ,051 | -3,739 | ,006 |
| | | P2 | -2,367(*) | ,812 | ,019 | -4,239 | -,494 |
| | | self | -1,000 | ,812 | ,253 | -2,872 | ,872 |
| | self | Normal | -1,567 | ,812 | ,090 | -3,439 | ,306 |
| | | P1 | -,867 | ,812 | ,317 | -2,739 | 1,006 |
| | | P2 | -1,367 | ,812 | ,131 | -3,239 | ,506 |
| | | P3 | 1,000 | ,812 | ,253 | -,872 | 2,872 |
| Length of pods | Normal | P1 | -1,100 | 1,032 | ,317 | -3,479 | 1,279 |
| | | P2 | -1,667 | 1,032 | ,145 | -4,045 | ,712 |
| | | P3 | -2,700(*) | 1,032 | ,031 | -5,079 | -,321 |
| | | self | -1,300 | 1,032 | ,243 | -3,679 | 1,079 |
| | P1 | Normal | 1,100 | 1,032 | ,317 | -1,279 | 3,479 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | P2 | -,567 | 1,032 | ,598 | -2,945 | 1,812 |
| | | P3 | -1,600 | 1,032 | ,159 | -3,979 | ,779 |
| | | self | -,200 | 1,032 | ,851 | -2,579 | 2,179 |
| | P2 | Normal | 1,667 | 1,032 | ,145 | -,712 | 4,045 |
| | | P1 | ,567 | 1,032 | ,598 | -1,812 | 2,945 |
| | | P3 | -1,033 | 1,032 | ,346 | -3,412 | 1,345 |
| | | self | ,367 | 1,032 | ,731 | -2,012 | 2,745 |
| | P3 | Normal | 2,700(*) | 1,032 | ,031 | ,321 | 5,079 |
| | | P1 | 1,600 | 1,032 | ,159 | -,779 | 3,979 |
| | | P2 | 1,033 | 1,032 | ,346 | -1,345 | 3,412 |
| | | self | 1,400 | 1,032 | ,212 | -,979 | 3,779 |
| | self | Normal | 1,300 | 1,032 | ,243 | -1,079 | 3,679 |
| | | P1 | ,200 | 1,032 | ,851 | -2,179 | 2,579 |
| | | P2 | -,367 | 1,032 | ,731 | -2,745 | 2,012 |
| | | P3 | -1,400 | 1,032 | ,212 | -3,779 | ,979 |
| N of Pods | Normal | P1 | 11,333 | 30,665 | ,721 | -59,380 | 82,047 |
| | | P2 | 5,300 | 30,665 | ,867 | -65,413 | 76,013 |
| | | P3 | -96,233(*) | 30,665 | ,014 | -166,947 | -25,520 |
| | | self | -40,500 | 30,665 | ,223 | -111,213 | 30,213 |
| | P1 | Normal | -11,333 | 30,665 | ,721 | -82,047 | 59,380 |
| | | P2 | -6,033 | 30,665 | ,849 | -76,747 | 64,680 |
| | | P3 | -107,567(*) | 30,665 | ,008 | -178,280 | -36,853 |
| | | self | -51,833 | 30,665 | ,129 | -122,547 | 18,880 |
| | P2 | Normal | -5,300 | 30,665 | ,867 | -76,013 | 65,413 |
| | | P1 | 6,033 | 30,665 | ,849 | -64,680 | 76,747 |
| | | P3 | -101,533(*) | 30,665 | ,011 | -172,247 | -30,820 |
| | | self | -45,800 | 30,665 | ,174 | -116,513 | 24,913 |
| | P3 | Normal | 96,233(*) | 30,665 | ,014 | 25,520 | 166,947 |
| | | P1 | 107,567(*) | 30,665 | ,008 | 36,853 | 178,280 |
| | | P2 | 101,533(*) | 30,665 | ,011 | 30,820 | 172,247 |
| | | self | 55,733 | 30,665 | ,107 | -14,980 | 126,447 |
| | self | Normal | 40,500 | 30,665 | ,223 | -30,213 | 111,213 |
| | | P1 | 51,833 | 30,665 | ,129 | -18,880 | 122,547 |
| | | P2 | 45,800 | 30,665 | ,174 | -24,913 | 116,513 |
| | | P3 | -55,733 | 30,665 | ,107 | -126,447 | 14,980 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fresh Weight ORIENTE | Normal | P1 | 124,033 | 469,650 | ,798 | -958,983 | 1207,049 |
| | | P2 | 97,333 | 469,650 | ,841 | -985,683 | 1180,349 |
| | | P3 | -1275,200(*) | 469,650 | ,026 | -2358,216 | -192,184 |
| | | self | -619,333 | 469,650 | ,224 | -1702,349 | 463,683 |
| | P1 | Normal | -124,033 | 469,650 | ,798 | -1207,049 | 958,983 |
| | | P2 | -26,700 | 469,650 | ,956 | -1109,716 | 1056,316 |
| | | P3 | -1399,233(*) | 469,650 | ,018 | -2482,249 | -316,217 |
| | | self | -743,367 | 469,650 | ,152 | -1826,383 | 339,649 |
| | P2 | Normal | -97,333 | 469,650 | ,841 | -1180,349 | 985,683 |
| | | P1 | 26,700 | 469,650 | ,956 | -1056,316 | 1109,716 |
| | | P3 | -1372,533(*) | 469,650 | ,019 | -2455,549 | -289,517 |
| | | self | -716,667 | 469,650 | ,166 | -1799,683 | 366,349 |
| | P3 | Normal | 1275,200(*) | 469,650 | ,026 | 192,184 | 2358,216 |
| | | P1 | 1399,233(*) | 469,650 | ,018 | 316,217 | 2482,249 |
| | | P2 | 1372,533(*) | 469,650 | ,019 | 289,517 | 2455,549 |
| | | self | 655,867 | 469,650 | ,200 | -427,149 | 1738,883 |
| | self | Normal | 619,333 | 469,650 | ,224 | -463,683 | 1702,349 |
| | | P1 | 743,367 | 469,650 | ,152 | -339,649 | 1826,383 |
| | | P2 | 716,667 | 469,650 | ,166 | -366,349 | 1799,683 |
| | | P3 | -655,867 | 469,650 | ,200 | -1738,883 | 427,149 |
| Minor defects | Normal | P1 | 5,533 | 5,841 | ,371 | -7,937 | 19,004 |
| | | P2 | 3,667 | 5,841 | ,548 | -9,804 | 17,137 |
| | | P3 | -15,000(*) | 5,841 | ,033 | -28,470 | -1,530 |
| | | self | -3,067 | 5,841 | ,614 | -16,537 | 10,404 |
| | P1 | Normal | -5,533 | 5,841 | ,371 | -19,004 | 7,937 |
| | | P2 | -1,867 | 5,841 | ,757 | -15,337 | 11,604 |
| | | P3 | -20,533(*) | 5,841 | ,008 | -34,004 | -7,063 |
| | | self | -8,600 | 5,841 | ,179 | -22,070 | 4,870 |
| | P2 | Normal | -3,667 | 5,841 | ,548 | -17,137 | 9,804 |
| | | P1 | 1,867 | 5,841 | ,757 | -11,604 | 15,337 |
| | | P3 | -18,667(*) | 5,841 | ,013 | -32,137 | -5,196 |
| | | self | -6,733 | 5,841 | ,282 | -20,204 | 6,737 |
| | P3 | Normal | 15,000(*) | 5,841 | ,033 | 1,530 | 28,470 |
| | | P1 | 20,533(*) | 5,841 | ,008 | 7,063 | 34,004 |
| | | P2 | 18,667(*) | 5,841 | ,013 | 5,196 | 32,137 |
| | | self | 11,933 | 5,841 | ,075 | -1,537 | 25,404 |
| | self | Normal | 3,067 | 5,841 | ,614 | -10,404 | 16,537 |
| | | P1 | 8,600 | 5,841 | ,179 | -4,870 | 22,070 |
| | | P2 | 6,733 | 5,841 | ,282 | -6,737 | 20,204 |
| | | P3 | -11,933 | 5,841 | ,075 | -25,404 | 1,537 |
| Serious defects | Normal | P1 | ,567 | 3,477 | ,875 | -7,452 | 8,586 |
| | | P2 | -2,833 | 3,477 | ,439 | -10,852 | 5,186 |
| | | P3 | -6,933 | 3,477 | ,081 | -14,952 | 1,086 |
| | | self | -4,300 | 3,477 | ,251 | -12,319 | 3,719 |
| | P1 | Normal | -,567 | 3,477 | ,875 | -8,586 | 7,452 |
| | | P2 | -3,400 | 3,477 | ,357 | -11,419 | 4,619 |
| | | P3 | -7,500 | 3,477 | ,063 | -15,519 | ,519 |
| | | self | -4,867 | 3,477 | ,199 | -12,886 | 3,152 |
| | P2 | Normal | 2,833 | 3,477 | ,439 | -5,186 | 10,852 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | P1 | 3,400 | 3,477 | ,357 | -4,619 | 11,419 |
| | | P3 | -4,100 | 3,477 | ,272 | -12,119 | 3,919 |
| | | self | -1,467 | 3,477 | ,684 | -9,486 | 6,552 |
| | P3 | Normal | 6,933 | 3,477 | ,081 | -1,086 | 14,952 |
| | | P1 | 7,500 | 3,477 | ,063 | -,519 | 15,519 |
| | | P2 | 4,100 | 3,477 | ,272 | -3,919 | 12,119 |
| | | self | 2,633 | 3,477 | ,471 | -5,386 | 10,652 |
| | self | Normal | 4,300 | 3,477 | ,251 | -3,719 | 12,319 |
| | | P1 | 4,867 | 3,477 | ,199 | -3,152 | 12,886 |
| | | P2 | 1,467 | 3,477 | ,684 | -6,552 | 9,486 |
| | | P3 | -2,633 | 3,477 | ,471 | -10,652 | 5,386 |
| Diseases | Normal | P1 | ,567 | 1,472 | ,710 | -2,828 | 3,961 |
| | | P2 | -,967 | 1,472 | ,530 | -4,361 | 2,428 |
| | | P3 | -,833 | 1,472 | ,587 | -4,228 | 2,561 |
| | | self | -,167 | 1,472 | ,913 | -3,561 | 3,228 |
| | P1 | Normal | -,567 | 1,472 | ,710 | -3,961 | 2,828 |
| | | P2 | -1,533 | 1,472 | ,328 | -4,928 | 1,861 |
| | | P3 | -1,400 | 1,472 | ,369 | -4,795 | 1,995 |
| | | self | -,733 | 1,472 | ,632 | -4,128 | 2,661 |
| | P2 | Normal | ,967 | 1,472 | ,530 | -2,428 | 4,361 |
| | | P1 | 1,533 | 1,472 | ,328 | -1,861 | 4,928 |
| | | P3 | ,133 | 1,472 | ,930 | -3,261 | 3,528 |
| | | self | ,800 | 1,472 | ,602 | -2,595 | 4,195 |
| | P3 | Normal | ,833 | 1,472 | ,587 | -2,561 | 4,228 |
| | | P1 | 1,400 | 1,472 | ,369 | -1,995 | 4,795 |
| | | P2 | -,133 | 1,472 | ,930 | -3,528 | 3,261 |
| | | self | ,667 | 1,472 | ,663 | -2,728 | 4,061 |
| | self | Normal | ,167 | 1,472 | ,913 | -3,228 | 3,561 |
| | | P1 | ,733 | 1,472 | ,632 | -2,661 | 4,128 |
| | | P2 | -,800 | 1,472 | ,602 | -4,195 | 2,595 |
| | | P3 | -,667 | 1,472 | ,663 | -4,061 | 2,728 |
| Date of first flower | Normal | P1 | -3,667 | 2,423 | ,169 | -9,253 | 1,920 |
| | | P2 | ,500 | 2,423 | ,842 | -5,087 | 6,087 |
| | | P3 | 2,167 | 2,423 | ,397 | -3,420 | 7,753 |
| | | self | -4,000 | 2,423 | ,137 | -9,587 | 1,587 |
| | P1 | Normal | 3,667 | 2,423 | ,169 | -1,920 | 9,253 |
| | | P2 | 4,167 | 2,423 | ,124 | -1,420 | 9,753 |
| | | P3 | 5,833(*) | 2,423 | ,043 | ,247 | 11,420 |
| | | self | -,333 | 2,423 | ,894 | -5,920 | 5,253 |
| | P2 | Normal | -,500 | 2,423 | ,842 | -6,087 | 5,087 |
| | | P1 | -4,167 | 2,423 | ,124 | -9,753 | 1,420 |
| | | P3 | 1,667 | 2,423 | ,511 | -3,920 | 7,253 |
| | | self | -4,500 | 2,423 | ,100 | -10,087 | 1,087 |
| | P3 | Normal | -2,167 | 2,423 | ,397 | -7,753 | 3,420 |
| | | P1 | -5,833(*) | 2,423 | ,043 | -11,420 | -,247 |
| | | P2 | -1,667 | 2,423 | ,511 | -7,253 | 3,920 |
| | | self | -6,167(*) | 2,423 | ,034 | -11,753 | -,580 |
| | self | Normal | 4,000 | 2,423 | ,137 | -1,587 | 9,587 |
| | | P1 | ,333 | 2,423 | ,894 | -5,253 | 5,920 |
| | | P2 | 4,500 | 2,423 | ,100 | -1,087 | 10,087 |
| | | P3 | 6,167(*) | 2,423 | ,034 | ,580 | 11,753 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date of first pod | Normal | P1 | -3,500 | 3,097 | ,291 | -10,643 | 3,643 |
| | | P2 | ,333 | 3,097 | ,917 | -6,809 | 7,476 |
| | | P3 | ,500 | 3,097 | ,876 | -6,643 | 7,643 |
| | | self | -1,833 | 3,097 | ,570 | -8,976 | 5,309 |
| | P1 | Normal | 3,500 | 3,097 | ,291 | -3,643 | 10,643 |
| | | P2 | 3,833 | 3,097 | ,251 | -3,309 | 10,976 |
| | | P3 | 4,000 | 3,097 | ,233 | -3,143 | 11,143 |
| | | self | 1,667 | 3,097 | ,605 | -5,476 | 8,809 |
| | P2 | Normal | -,333 | 3,097 | ,917 | -7,476 | 6,809 |
| | | P1 | -3,833 | 3,097 | ,251 | -10,976 | 3,309 |
| | | P3 | ,167 | 3,097 | ,958 | -6,976 | 7,309 |
| | | self | -2,167 | 3,097 | ,504 | -9,309 | 4,976 |
| | P3 | Normal | -,500 | 3,097 | ,876 | -7,643 | 6,643 |
| | | P1 | -4,000 | 3,097 | ,233 | -11,143 | 3,143 |
| | | P2 | -,167 | 3,097 | ,958 | -7,309 | 6,976 |
| | | self | -2,333 | 3,097 | ,473 | -9,476 | 4,809 |
| | self | Normal | 1,833 | 3,097 | ,570 | -5,309 | 8,976 |
| | | P1 | -1,667 | 3,097 | ,605 | -8,809 | 5,476 |
| | | P2 | 2,167 | 3,097 | ,504 | -4,976 | 9,309 |
| | | P3 | 2,333 | 3,097 | ,473 | -4,809 | 9,476 |

Based on estimated marginal means

* The mean difference is significant at the ,05 level.

a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

## Statistical analysis of the data for the scion cultivar Rajado

**Tests of Between-Subjects Effects**

| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Rootstock | Dead Stems | 6,933 | 4 | 1,733 | 1,300 | ,348 |
| | Dry Matter | 4,956 | 4 | 1,239 | 1,406 | ,315 |
| | Length of pods | 8,980 | 4 | 2,245 | 2,235 | ,155 |
| | N of Pods | 4962,523 | 4 | 1240,631 | 1,440 | ,306 |
| | Fresh Weight | 527220,727 | 4 | 131805,182 | 1,806 | ,221 |
| | Minor defects | 533,963 | 4 | 133,491 | 1,733 | ,235 |
| | Serious defects | 48,809 | 4 | 12,202 | ,251 | ,901 |
| | Diseases | 11,663 | 4 | 2,916 | ,772 | ,573 |
| | Date of first flower | 186,067 | 4 | 46,517 | 3,307 | ,070 |
| | Date of first pod | 336,900 | 4 | 84,225 | 8,497 | ,006 |
| Scion cv | Dead Stems | 3,333 | 2 | 1,667 | 1,250 | ,337 |
| | Dry Matter | 3,892 | 2 | 1,946 | 2,209 | ,172 |
| | Length of pods | 2,937 | 2 | 1,469 | 1,462 | ,288 |
| | N of Pods | 2750,757 | 2 | 1375,379 | 1,597 | ,261 |
| | Fresh Weight | 271886,405 | 2 | 135943,203 | 1,863 | ,217 |
| | Minor defects | 37,296 | 2 | 18,648 | ,242 | ,791 |
| | Serious defects | 108,801 | 2 | 54,401 | 1,118 | ,373 |
| | Diseases | ,585 | 2 | ,293 | ,077 | ,926 |
| | Date of first flower | 22,300 | 2 | 11,150 | ,793 | ,485 |
| | Date of first pod | 20,033 | 2 | 10,017 | 1,011 | ,406 |
| Error | Dead Stems | 10,667 | 8 | 1,333 | | |
| | Dry Matter | 7,048 | 8 | ,881 | | |
| | Length of pods | 8,036 | 8 | 1,005 | | |
| | N of Pods | 6891,209 | 8 | 861,401 | | |
| | Fresh Weight | 583883,161 | 8 | 72985,395 | | |
| | Minor defects | 616,237 | 8 | 77,030 | | |
| | Serious defects | 389,359 | 8 | 48,670 | | |
| | Diseases | 30,221 | 8 | 3,778 | | |
| | Date of first flower | 112,533 | 8 | 14,067 | | |
| | Date of first pod | 79,300 | 8 | 9,913 | | |

a R Squared = ,490 (Adjusted R Squared = ,108)
b R Squared = ,557 (Adjusted R Squared = ,224)
c R Squared = ,597 (Adjusted R Squared = ,295)
d R Squared = ,528 (Adjusted R Squared = ,174)
e R Squared = ,578 (Adjusted R Squared = ,261)
f R Squared = ,481 (Adjusted R Squared = ,092)
g R Squared = ,288 (Adjusted R Squared = -,246)
h R Squared = ,288 (Adjusted R Squared = -,245)
i R Squared = ,649 (Adjusted R Squared = ,386)
j R Squared = ,818 (Adjusted R Squared = ,682)

**Pairwise Comparisons**

| Dependent Variable | (I) PortaEnx | (J) PortaEnx | Mean Difference (I-J) | Std. Error | Sig.(a) | 95% Confidence Interval for Difference(a) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Upper Bound | Lower Bound |
| Dead Stems | Normal | P1 | -,667 | ,943 | ,500 | -2,841 | 1,507 |
| | | P2 | -1,333 | ,943 | ,195 | -3,507 | ,841 |
| | | P3 | 1,11E-016 | ,943 | 1,000 | -2,174 | 2,174 |
| | | self | ,667 | ,943 | ,500 | -1,507 | 2,841 |
| | P1 | Normal | ,667 | ,943 | ,500 | -1,507 | 2,841 |
| | | P2 | -,667 | ,943 | ,500 | -2,841 | 1,507 |
| | | P3 | ,667 | ,943 | ,500 | -1,507 | 2,841 |
| | | self | 1,333 | ,943 | ,195 | -,841 | 3,507 |
| | P2 | Normal | 1,333 | ,943 | ,195 | -,841 | 3,507 |
| | | P1 | ,667 | ,943 | ,500 | -1,507 | 2,841 |
| | | P3 | 1,333 | ,943 | ,195 | -,841 | 3,507 |
| | | self | 2,000 | ,943 | ,067 | -,174 | 4,174 |
| | P3 | Normal | -1,11E-016 | ,943 | 1,000 | -2,174 | 2,174 |
| | | P1 | -,667 | ,943 | ,500 | -2,841 | 1,507 |
| | | P2 | -1,333 | ,943 | ,195 | -3,507 | ,841 |
| | | self | ,667 | ,943 | ,500 | -1,507 | 2,841 |
| | self | Normal | -,667 | ,943 | ,500 | -2,841 | 1,507 |
| | | P1 | -1,333 | ,943 | ,195 | -3,507 | ,841 |
| | | P2 | -2,000 | ,943 | ,067 | -4,174 | ,174 |
| | | P3 | -,667 | ,943 | ,500 | -2,841 | 1,507 |
| Dry Matter | Normal | P1 | ,233 | ,766 | ,769 | -1,534 | 2,001 |
| | | P2 | -,600 | ,766 | ,456 | -2,367 | 1,167 |
| | | P3 | 1,100 | ,766 | ,189 | -,667 | 2,867 |
| | | self | ,633 | ,766 | ,433 | -1,134 | 2,401 |
| | P1 | Normal | -,233 | ,766 | ,769 | -2,001 | 1,534 |
| | | P2 | -,833 | ,766 | ,309 | -2,601 | ,934 |
| | | P3 | ,867 | ,766 | ,291 | -,901 | 2,634 |
| | | self | ,400 | ,766 | ,616 | -1,367 | 2,167 |
| | P2 | Normal | ,600 | ,766 | ,456 | -1,167 | 2,367 |
| | | P1 | ,833 | ,766 | ,309 | -,934 | 2,601 |
| | | P3 | 1,700 | ,766 | ,057 | -,067 | 3,467 |
| | | self | 1,233 | ,766 | ,146 | -,534 | 3,001 |
| | P3 | Normal | -1,100 | ,766 | ,189 | -2,867 | ,667 |
| | | P1 | -,867 | ,766 | ,291 | -2,634 | ,901 |
| | | P2 | -1,700 | ,766 | ,057 | -3,467 | ,067 |
| | | self | -,467 | ,766 | ,559 | -2,234 | 1,301 |
| | self | Normal | -,633 | ,766 | ,433 | -2,401 | 1,134 |
| | | P1 | -,400 | ,766 | ,616 | -2,167 | 1,367 |
| | | P2 | -1,233 | ,766 | ,146 | -3,001 | ,534 |
| | | P3 | ,467 | ,766 | ,559 | -1,301 | 2,234 |
| Length | Normal | P1 | ,167 | ,818 | ,844 | -1,720 | 2,054 |
| | | P2 | -,933 | ,818 | ,287 | -2,820 | ,954 |
| | | P3 | -1,433 | ,818 | ,118 | -3,320 | ,454 |
| | | self | ,700 | ,818 | ,417 | -1,187 | 2,587 |
| | P1 | Normal | -,167 | ,818 | ,844 | -2,054 | 1,720 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | P2 | -1,100 | ,818 | ,216 | -2,987 | ,787 |
| | | P3 | -1,600 | ,818 | ,086 | -3,487 | ,287 |
| | | self | ,533 | ,818 | ,533 | -1,354 | 2,420 |
| | P2 | Normal | ,933 | ,818 | ,287 | -,954 | 2,820 |
| | | P1 | 1,100 | ,818 | ,216 | -,787 | 2,987 |
| | | P3 | -,500 | ,818 | ,558 | -2,387 | 1,387 |
| | | self | 1,633 | ,818 | ,081 | -,254 | 3,520 |
| | P3 | Normal | 1,433 | ,818 | ,118 | -,454 | 3,320 |
| | | P1 | 1,600 | ,818 | ,086 | -,287 | 3,487 |
| | | P2 | ,500 | ,818 | ,558 | -1,387 | 2,387 |
| | | self | 2,133(*) | ,818 | ,031 | ,246 | 4,020 |
| | self | Normal | -,700 | ,818 | ,417 | -2,587 | 1,187 |
| | | P1 | -,533 | ,818 | ,533 | -2,420 | 1,354 |
| | | P2 | -1,633 | ,818 | ,081 | -3,520 | ,254 |
| | | P3 | -2,133(*) | ,818 | ,031 | -4,020 | -,246 |
| N of Pods | Normal | P1 | -1,367 | 23,964 | ,956 | -56,627 | 53,894 |
| | | P2 | -29,333 | 23,964 | ,256 | -84,594 | 25,927 |
| | | P3 | -47,600 | 23,964 | ,082 | -102,861 | 7,661 |
| | | self | -11,000 | 23,964 | ,658 | -66,261 | 44,261 |
| | P1 | Normal | 1,367 | 23,964 | ,956 | -53,894 | 56,627 |
| | | P2 | -27,967 | 23,964 | ,277 | -83,227 | 27,294 |
| | | P3 | -46,233 | 23,964 | ,090 | -101,494 | 9,027 |
| | | self | -9,633 | 23,964 | ,698 | -64,894 | 45,627 |
| | P2 | Normal | 29,333 | 23,964 | ,256 | -25,927 | 84,594 |
| | | P1 | 27,967 | 23,964 | ,277 | -27,294 | 83,227 |
| | | P3 | -18,267 | 23,964 | ,468 | -73,527 | 36,994 |
| | | self | 18,333 | 23,964 | ,466 | -36,927 | 73,594 |
| | P3 | Normal | 47,600 | 23,964 | ,082 | -7,661 | 102,861 |
| | | P1 | 46,233 | 23,964 | ,090 | -9,027 | 101,494 |
| | | P2 | 18,267 | 23,964 | ,468 | -36,994 | 73,527 |
| | | self | 36,600 | 23,964 | ,165 | -18,661 | 91,861 |
| | self | Normal | 11,000 | 23,964 | ,658 | -44,261 | 66,261 |
| | | P1 | 9,633 | 23,964 | ,698 | -45,627 | 64,894 |
| | | P2 | -18,333 | 23,964 | ,466 | -73,594 | 36,927 |
| | | P3 | -36,600 | 23,964 | ,165 | -91,861 | 18,661 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fresh Weight RAJADO | Normal | P1 | -72,100 | 220,583 | ,752 | -580,766 | 436,566 |
| | | P2 | -307,000 | 220,583 | ,201 | -815,666 | 201,666 |
| | | P3 | -492,900 | 220,583 | ,056 | -1001,566 | 15,766 |
| | | self | -46,833 | 220,583 | ,837 | -555,499 | 461,832 |
| | P1 | Normal | 72,100 | 220,583 | ,752 | -436,566 | 580,766 |
| | | P2 | -234,900 | 220,583 | ,318 | -743,566 | 273,766 |
| | | P3 | -420,800 | 220,583 | ,093 | -929,466 | 87,866 |
| | | self | 25,267 | 220,583 | ,912 | -483,399 | 533,932 |
| | P2 | Normal | 307,000 | 220,583 | ,201 | -201,666 | 815,666 |
| | | P1 | 234,900 | 220,583 | ,318 | -273,766 | 743,566 |
| | | P3 | -185,900 | 220,583 | ,424 | -694,566 | 322,766 |
| | | self | 260,167 | 220,583 | ,272 | -248,499 | 768,832 |
| | P3 | Normal | 492,900 | 220,583 | ,056 | -15,766 | 1001,566 |
| | | P1 | 420,800 | 220,583 | ,093 | -87,866 | 929,466 |
| | | P2 | 185,900 | 220,583 | ,424 | -322,766 | 694,566 |
| | | self | 446,067 | 220,583 | ,078 | -62,599 | 954,732 |
| | self | Normal | 46,833 | 220,583 | ,837 | -461,832 | 555,499 |
| | | P1 | -25,267 | 220,583 | ,912 | -533,932 | 483,399 |
| | | P2 | -260,167 | 220,583 | ,272 | -768,832 | 248,499 |
| | | P3 | -446,067 | 220,583 | ,078 | -954,732 | 62,599 |
| Minor defects | Normal | P1 | -,933 | 7,166 | ,900 | -17,458 | 15,592 |
| | | P2 | -10,867 | 7,166 | ,168 | -27,392 | 5,658 |
| | | P3 | -15,167 | 7,166 | ,067 | -31,692 | 1,358 |
| | | self | -3,067 | 7,166 | ,680 | -19,592 | 13,458 |
| | P1 | Normal | ,933 | 7,166 | ,900 | -15,592 | 17,458 |
| | | P2 | -9,933 | 7,166 | ,203 | -26,458 | 6,592 |
| | | P3 | -14,233 | 7,166 | ,082 | -30,758 | 2,292 |
| | | self | -2,133 | 7,166 | ,774 | -18,658 | 14,392 |
| | P2 | Normal | 10,867 | 7,166 | ,168 | -5,658 | 27,392 |
| | | P1 | 9,933 | 7,166 | ,203 | -6,592 | 26,458 |
| | | P3 | -4,300 | 7,166 | ,565 | -20,825 | 12,225 |
| | | self | 7,800 | 7,166 | ,308 | -8,725 | 24,325 |
| | P3 | Normal | 15,167 | 7,166 | ,067 | -1,358 | 31,692 |
| | | P1 | 14,233 | 7,166 | ,082 | -2,292 | 30,758 |
| | | P2 | 4,300 | 7,166 | ,565 | -12,225 | 20,825 |
| | | self | 12,100 | 7,166 | ,130 | -4,425 | 28,625 |
| | self | Normal | 3,067 | 7,166 | ,680 | -13,458 | 19,592 |
| | | P1 | 2,133 | 7,166 | ,774 | -14,392 | 18,658 |
| | | P2 | -7,800 | 7,166 | ,308 | -24,325 | 8,725 |
| | | P3 | -12,100 | 7,166 | ,130 | -28,625 | 4,425 |
| Serious defects | Normal | P1 | ,133 | 5,696 | ,982 | -13,002 | 13,269 |
| | | P2 | -4,500 | 5,696 | ,452 | -17,635 | 8,635 |
| | | P3 | -1,433 | 5,696 | ,808 | -14,569 | 11,702 |
| | | self | ,267 | 5,696 | ,964 | -12,869 | 13,402 |
| | P1 | Normal | -,133 | 5,696 | ,982 | -13,269 | 13,002 |
| | | P2 | -4,633 | 5,696 | ,440 | -17,769 | 8,502 |
| | | P3 | -1,567 | 5,696 | ,790 | -14,702 | 11,569 |
| | | self | ,133 | 5,696 | ,982 | -13,002 | 13,269 |
| | P2 | Normal | 4,500 | 5,696 | ,452 | -8,635 | 17,635 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | P1 | 4,633 | 5,696 | ,440 | -8,502 | 17,769 |
| | | P3 | 3,067 | 5,696 | ,605 | -10,069 | 16,202 |
| | | self | 4,767 | 5,696 | ,427 | -8,369 | 17,902 |
| | P3 | Normal | 1,433 | 5,696 | ,808 | -11,702 | 14,569 |
| | | P1 | 1,567 | 5,696 | ,790 | -11,569 | 14,702 |
| | | P2 | -3,067 | 5,696 | ,605 | -16,202 | 10,069 |
| | | self | 1,700 | 5,696 | ,773 | -11,435 | 14,835 |
| | self | Normal | -,267 | 5,696 | ,964 | -13,402 | 12,869 |
| | | P1 | -,133 | 5,696 | ,982 | -13,269 | 13,002 |
| | | P2 | -4,767 | 5,696 | ,427 | -17,902 | 8,369 |
| | | P3 | -1,700 | 5,696 | ,773 | -14,835 | 11,435 |
| Diseases | Normal | P1 | 2,533 | 1,587 | ,149 | -1,126 | 6,193 |
| | | P2 | 1,433 | 1,587 | ,393 | -2,226 | 5,093 |
| | | P3 | 1,333 | 1,587 | ,425 | -2,326 | 4,993 |
| | | self | 2,233 | 1,587 | ,197 | -1,426 | 5,893 |
| | P1 | Normal | -2,533 | 1,587 | ,149 | -6,193 | 1,126 |
| | | P2 | -1,100 | 1,587 | ,508 | -4,760 | 2,560 |
| | | P3 | -1,200 | 1,587 | ,471 | -4,860 | 2,460 |
| | | self | -,300 | 1,587 | ,855 | -3,960 | 3,360 |
| | P2 | Normal | -1,433 | 1,587 | ,393 | -5,093 | 2,226 |
| | | P1 | 1,100 | 1,587 | ,508 | -2,560 | 4,760 |
| | | P3 | -,100 | 1,587 | ,951 | -3,760 | 3,560 |
| | | self | ,800 | 1,587 | ,628 | -2,860 | 4,460 |
| | P3 | Normal | -1,333 | 1,587 | ,425 | -4,993 | 2,326 |
| | | P1 | 1,200 | 1,587 | ,471 | -2,460 | 4,860 |
| | | P2 | ,100 | 1,587 | ,951 | -3,560 | 3,760 |
| | | self | ,900 | 1,587 | ,586 | -2,760 | 4,560 |
| | self | Normal | -2,233 | 1,587 | ,197 | -5,893 | 1,426 |
| | | P1 | ,300 | 1,587 | ,855 | -3,360 | 3,960 |
| | | P2 | -,800 | 1,587 | ,628 | -4,460 | 2,860 |
| | | P3 | -,900 | 1,587 | ,586 | -4,560 | 2,760 |
| Date of first flower | Normal | P1 | -7,333(*) | 3,062 | ,044 | -14,395 | -,272 |
| | | P2 | -4,333 | 3,062 | ,195 | -11,395 | 2,728 |
| | | P3 | -1,833 | 3,062 | ,566 | -8,895 | 5,228 |
| | | self | -9,667(*) | 3,062 | ,013 | -16,728 | -2,605 |
| | P1 | Normal | 7,333(*) | 3,062 | ,044 | ,272 | 14,395 |
| | | P2 | 3,000 | 3,062 | ,356 | -4,062 | 10,062 |
| | | P3 | 5,500 | 3,062 | ,110 | -1,562 | 12,562 |
| | | self | -2,333 | 3,062 | ,468 | -9,395 | 4,728 |
| | P2 | Normal | 4,333 | 3,062 | ,195 | -2,728 | 11,395 |
| | | P1 | -3,000 | 3,062 | ,356 | -10,062 | 4,062 |
| | | P3 | 2,500 | 3,062 | ,438 | -4,562 | 9,562 |
| | | self | -5,333 | 3,062 | ,120 | -12,395 | 1,728 |
| | P3 | Normal | 1,833 | 3,062 | ,566 | -5,228 | 8,895 |
| | | P1 | -5,500 | 3,062 | ,110 | -12,562 | 1,562 |
| | | P2 | -2,500 | 3,062 | ,438 | -9,562 | 4,562 |
| | | self | -7,833(*) | 3,062 | ,034 | -14,895 | -,772 |
| | self | Normal | 9,667(*) | 3,062 | ,013 | 2,605 | 16,728 |
| | | P1 | 2,333 | 3,062 | ,468 | -4,728 | 9,395 |
| | | P2 | 5,333 | 3,062 | ,120 | -1,728 | 12,395 |
| | | P3 | 7,833(*) | 3,062 | ,034 | ,772 | 14,895 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date of first pod | Normal | P1 | -10,833(*) | 2,571 | ,003 | -16,761 | -4,905 |
| | | P2 | -5,000 | 2,571 | ,088 | -10,928 | ,928 |
| | | P3 | -4,833 | 2,571 | ,097 | -10,761 | 1,095 |
| | | self | -13,333(*) | 2,571 | ,001 | -19,261 | -7,405 |
| | P1 | Normal | 10,833(*) | 2,571 | ,003 | 4,905 | 16,761 |
| | | P2 | 5,833 | 2,571 | ,053 | -,095 | 11,761 |
| | | P3 | 6,000(*) | 2,571 | ,048 | ,072 | 11,928 |
| | | self | -2,500 | 2,571 | ,359 | -8,428 | 3,428 |
| | P2 | Normal | 5,000 | 2,571 | ,088 | -,928 | 10,928 |
| | | P1 | -5,833 | 2,571 | ,053 | -11,761 | ,095 |
| | | P3 | ,167 | 2,571 | ,950 | -5,761 | 6,095 |
| | | self | -8,333(*) | 2,571 | ,012 | -14,261 | -2,405 |
| | P3 | Normal | 4,833 | 2,571 | ,097 | -1,095 | 10,761 |
| | | P1 | -6,000(*) | 2,571 | ,048 | -11,928 | -,072 |
| | | P2 | -,167 | 2,571 | ,950 | -6,095 | 5,761 |
| | | self | -8,500(*) | 2,571 | ,011 | -14,428 | -2,572 |
| | self | Normal | 13,333(*) | 2,571 | ,001 | 7,405 | 19,261 |
| | | P1 | 2,500 | 2,571 | ,359 | -3,428 | 8,428 |
| | | P2 | 8,333(*) | 2,571 | ,012 | 2,405 | 14,261 |
| | | P3 | 8,500(*) | 2,571 | ,011 | 2,572 | 14,428 |

Based on estimated marginal means
* The mean difference is significant at the ,05 level.
a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

## Statistical analysis of the data for scion cultivars Rajado and Oriente combined

**Tests of Between-Subjects Effects**

*** p>0.05 the differences between the treatments are not significant**
**p<=0.05 the treatments are significantly different**

| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | F | p * |
|---|---|---|---|---|---|---|
| Rootstock | Dead Stems | 14,333 | 4 | 3,583 | 2,234 | ,106 |
| | Dry Matter | 16,685 | 4 | 4,171 | 4,798 | ,008 |
| | Length of pods | 17,112 | 4 | 4,278 | 3,247 | ,036 |
| | N of Pods | 22871,312 | 4 | 5717,828 | 4,357 | ,012 |
| | Fresh Weight | 3409380,030 | 4 | 852345,008 | 3,647 | ,024 |
| | Minor defects | 1077,005 | 4 | 269,251 | 4,139 | ,015 |
| | Serious defects | 102,125 | 4 | 25,531 | ,614 | ,658 |
| | Diseases | 10,238 | 4 | 2,560 | ,808 | ,536 |
| | Date of first flower | 245,867 | 4 | 61,467 | 5,720 | ,004 |
| | Date of first pod | 269,367 | 4 | 67,342 | 5,803 | ,004 |
| Scion Cv | Dead Stems | ,133 | 1 | ,133 | ,083 | ,776 |
| | Dry Matter | ,833 | 1 | ,833 | ,959 | ,341 |
| | Length of pods | 77,763 | 1 | 77,763 | 59,017 | ,000 |
| | N of Pods | 1633,932 | 1 | 1633,932 | 1,245 | ,279 |
| | Fresh Weight | 1952790,533 | 1 | 1952790,533 | 8,356 | ,010 |
| | Minor defects | 43,200 | 1 | 43,200 | ,664 | ,426 |
| | Serious defects | 22,707 | 1 | 22,707 | ,546 | ,469 |
| | Diseases | 3,201 | 1 | 3,201 | 1,010 | ,328 |
| | Date of first flower | 66,008 | 1 | 66,008 | 6,142 | ,023 |
| | Date of first pod | 18,408 | 1 | 18,408 | 1,586 | ,224 |
| Rootstock * Cv interaction | Dead Stems | 2,867 | 4 | ,717 | ,447 | ,773 |
| | Dry Matter | 1,787 | 4 | ,447 | ,514 | ,727 |
| | Length of pods | 3,299 | 4 | ,825 | ,626 | ,650 |
| | N of Pods | 6609,721 | 4 | 1652,430 | 1,259 | ,322 |
| | Fresh Weight | 1541849,270 | 4 | 385462,318 | 1,649 | ,205 |
| | Minor defects | 245,187 | 4 | 61,297 | ,942 | ,462 |
| | Serious defects | 62,065 | 4 | 15,516 | ,373 | ,825 |
| | Diseases | 6,182 | 4 | 1,546 | ,488 | ,745 |
| | Date of first flower | 28,367 | 4 | 7,092 | ,660 | ,628 |
| | Date of first pod | 103,300 | 4 | 25,825 | 2,225 | ,107 |
| Error | Dead Stems | 28,867 | 18 | 1,604 | | |
| | Dry Matter | 15,649 | 18 | ,869 | | |
| | Length of pods | 23,717 | 18 | 1,318 | | |
| | N of Pods | 23621,745 | 18 | 1312,319 | | |
| | Fresh Weight | 4206719,321 | 18 | 233706,629 | | |
| | Minor defects | 1170,862 | 18 | 65,048 | | |
| | Serious defects | 748,153 | 18 | 41,564 | | |
| | Diseases | 57,033 | 18 | 3,168 | | |
| | Date of first flower | 193,433 | 18 | 10,746 | | |
| | Date of first pod | 208,900 | 18 | 11,606 | | |

**Pairwise Comparisons**

**(*) the treatments are significantly different**

| Dependent Variable | (I) PortaEnx | (J) PortaEnx | Mean Difference (I-J) | Std. Error | Sig.(a) | 95% Confidence Interval for Difference(a) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Upper Bound | Lower Bound |
| Dead Stems | Normal | P1 | -1,167 | ,731 | ,128 | -2,703 | ,369 |
| | | P2 | -1,500 | ,731 | ,055 | -3,036 | ,036 |
| | | P3 | ,167 | ,731 | ,822 | -1,369 | 1,703 |
| | | self | 3,33E-016 | ,731 | 1,000 | -1,536 | 1,536 |
| | P1 | Normal | 1,167 | ,731 | ,128 | -,369 | 2,703 |
| | | P2 | -,333 | ,731 | ,654 | -1,869 | 1,203 |
| | | P3 | 1,333 | ,731 | ,085 | -,203 | 2,869 |
| | | self | 1,167 | ,731 | ,128 | -,369 | 2,703 |
| | P2 | Normal | 1,500 | ,731 | ,055 | -,036 | 3,036 |
| | | P1 | ,333 | ,731 | ,654 | -1,203 | 1,869 |
| | | P3 | 1,667(*) | ,731 | ,035 | ,131 | 3,203 |
| | | self | 1,500 | ,731 | ,055 | -,036 | 3,036 |
| | P3 | Normal | -,167 | ,731 | ,822 | -1,703 | 1,369 |
| | | P1 | -1,333 | ,731 | ,085 | -2,869 | ,203 |
| | | P2 | -1,667(*) | ,731 | ,035 | -3,203 | -,131 |
| | | self | -,167 | ,731 | ,822 | -1,703 | 1,369 |
| | self | Normal | -3,33E-016 | ,731 | 1,000 | -1,536 | 1,536 |
| | | P1 | -1,167 | ,731 | ,128 | -2,703 | ,369 |
| | | P2 | -1,500 | ,731 | ,055 | -3,036 | ,036 |
| | | P3 | ,167 | ,731 | ,822 | -1,369 | 1,703 |
| Dry matter | Normal | P1 | ,467 | ,538 | ,397 | -,664 | 1,598 |
| | | P2 | -,200 | ,538 | ,715 | -1,331 | ,931 |
| | | P3 | 1,833(*) | ,538 | ,003 | ,702 | 2,964 |
| | | self | 1,100 | ,538 | ,056 | -,031 | 2,231 |
| | P1 | Normal | -,467 | ,538 | ,397 | -1,598 | ,664 |
| | | P2 | -,667 | ,538 | ,231 | -1,798 | ,464 |
| | | P3 | 1,367(*) | ,538 | ,021 | ,236 | 2,498 |
| | | self | ,633 | ,538 | ,255 | -,498 | 1,764 |
| | P2 | Normal | ,200 | ,538 | ,715 | -,931 | 1,331 |
| | | P1 | ,667 | ,538 | ,231 | -,464 | 1,798 |
| | | P3 | 2,033(*) | ,538 | ,001 | ,902 | 3,164 |
| | | self | 1,300(*) | ,538 | ,027 | ,169 | 2,431 |
| | P3 | Normal | -1,833(*) | ,538 | ,003 | -2,964 | -,702 |
| | | P1 | -1,367(*) | ,538 | ,021 | -2,498 | -,236 |
| | | P2 | -2,033(*) | ,538 | ,001 | -3,164 | -,902 |
| | | self | -,733 | ,538 | ,190 | -1,864 | ,398 |
| | self | Normal | -1,100 | ,538 | ,056 | -2,231 | ,031 |
| | | P1 | -,633 | ,538 | ,255 | -1,764 | ,498 |
| | | P2 | -1,300(*) | ,538 | ,027 | -2,431 | -,169 |
| | | P3 | ,733 | ,538 | ,190 | -,398 | 1,864 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Length of pods | Normal | P1 | -,467 | ,663 | ,490 | -1,859 | ,926 |
| | | P2 | -1,300 | ,663 | ,065 | -2,692 | ,092 |
| | | P3 | -2,067(*) | ,663 | ,006 | -3,459 | -,674 |
| | | self | -,300 | ,663 | ,656 | -1,692 | 1,092 |
| | P1 | Normal | ,467 | ,663 | ,490 | -,926 | 1,859 |
| | | P2 | -,833 | ,663 | ,225 | -2,226 | ,559 |
| | | P3 | -1,600(*) | ,663 | ,027 | -2,992 | -,208 |
| | | self | ,167 | ,663 | ,804 | -1,226 | 1,559 |
| | P2 | Normal | 1,300 | ,663 | ,065 | -,092 | 2,692 |
| | | P1 | ,833 | ,663 | ,225 | -,559 | 2,226 |
| | | P3 | -,767 | ,663 | ,262 | -2,159 | ,626 |
| | | self | 1,000 | ,663 | ,149 | -,392 | 2,392 |
| | P3 | Normal | 2,067(*) | ,663 | ,006 | ,674 | 3,459 |
| | | P1 | 1,600(*) | ,663 | ,027 | ,208 | 2,992 |
| | | P2 | ,767 | ,663 | ,262 | -,626 | 2,159 |
| | | self | 1,767(*) | ,663 | ,016 | ,374 | 3,159 |
| | self | Normal | ,300 | ,663 | ,656 | -1,092 | 1,692 |
| | | P1 | -,167 | ,663 | ,804 | -1,559 | 1,226 |
| | | P2 | -1,000 | ,663 | ,149 | -2,392 | ,392 |
| | | P3 | -1,767(*) | ,663 | ,016 | -3,159 | -,374 |
| N of pods | Normal | P1 | 4,983 | 20,915 | ,814 | -38,958 | 48,924 |
| | | P2 | -12,017 | 20,915 | ,573 | -55,958 | 31,924 |
| | | P3 | -71,917(*) | 20,915 | ,003 | -115,858 | -27,976 |
| | | self | -25,750 | 20,915 | ,234 | -69,691 | 18,191 |
| | P1 | Normal | -4,983 | 20,915 | ,814 | -48,924 | 38,958 |
| | | P2 | -17,000 | 20,915 | ,427 | -60,941 | 26,941 |
| | | P3 | -76,900(*) | 20,915 | ,002 | -120,841 | -32,959 |
| | | self | -30,733 | 20,915 | ,159 | -74,674 | 13,208 |
| | P2 | Normal | 12,017 | 20,915 | ,573 | -31,924 | 55,958 |
| | | P1 | 17,000 | 20,915 | ,427 | -26,941 | 60,941 |
| | | P3 | -59,900(*) | 20,915 | ,010 | -103,841 | -15,959 |
| | | self | -13,733 | 20,915 | ,520 | -57,674 | 30,208 |
| | P3 | Normal | 71,917(*) | 20,915 | ,003 | 27,976 | 115,858 |
| | | P1 | 76,900(*) | 20,915 | ,002 | 32,959 | 120,841 |
| | | P2 | 59,900(*) | 20,915 | ,010 | 15,959 | 103,841 |
| | | self | 46,167(*) | 20,915 | ,041 | 2,226 | 90,108 |
| | self | Normal | 25,750 | 20,915 | ,234 | -18,191 | 69,691 |
| | | P1 | 30,733 | 20,915 | ,159 | -13,208 | 74,674 |
| | | P2 | 13,733 | 20,915 | ,520 | -30,208 | 57,674 |
| | | P3 | -46,167(*) | 20,915 | ,041 | -90,108 | -2,226 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fresh weight | Normal | P1 | 25,967 | 279,110 | ,927 | -560,421 | 612,354 |
| | | P2 | -104,833 | 279,110 | ,712 | -691,221 | 481,554 |
| | | P3 | -884,050(*) | 279,110 | ,005 | -1470,438 | -297,662 |
| | | self | -333,083 | 279,110 | ,248 | -919,471 | 253,304 |
| | P1 | Normal | -25,967 | 279,110 | ,927 | -612,354 | 560,421 |
| | | P2 | -130,800 | 279,110 | ,645 | -717,188 | 455,588 |
| | | P3 | -910,017(*) | 279,110 | ,004 | -1496,404 | -323,629 |
| | | self | -359,050 | 279,110 | ,215 | -945,438 | 227,338 |
| | P2 | Normal | 104,833 | 279,110 | ,712 | -481,554 | 691,221 |
| | | P1 | 130,800 | 279,110 | ,645 | -455,588 | 717,188 |
| | | P3 | -779,217(*) | 279,110 | ,012 | -1365,604 | -192,829 |
| | | self | -228,250 | 279,110 | ,424 | -814,638 | 358,138 |
| | P3 | Normal | 884,050(*) | 279,110 | ,005 | 297,662 | 1470,438 |
| | | P1 | 910,017(*) | 279,110 | ,004 | 323,629 | 1496,404 |
| | | P2 | 779,217(*) | 279,110 | ,012 | 192,829 | 1365,604 |
| | | self | 550,967 | 279,110 | ,064 | -35,421 | 1137,354 |
| | self | Normal | 333,083 | 279,110 | ,248 | -253,304 | 919,471 |
| | | P1 | 359,050 | 279,110 | ,215 | -227,338 | 945,438 |
| | | P2 | 228,250 | 279,110 | ,424 | -358,138 | 814,638 |
| | | P3 | -550,967 | 279,110 | ,064 | -1137,354 | 35,421 |
| Minor defects | Normal | P1 | 2,300 | 4,656 | ,627 | -7,483 | 12,083 |
| | | P2 | -3,600 | 4,656 | ,449 | -13,383 | 6,183 |
| | | P3 | -15,083(*) | 4,656 | ,005 | -24,866 | -5,300 |
| | | self | -3,067 | 4,656 | ,518 | -12,850 | 6,716 |
| | P1 | Normal | -2,300 | 4,656 | ,627 | -12,083 | 7,483 |
| | | P2 | -5,900 | 4,656 | ,221 | -15,683 | 3,883 |
| | | P3 | -17,383(*) | 4,656 | ,002 | -27,166 | -7,600 |
| | | self | -5,367 | 4,656 | ,264 | -15,150 | 4,416 |
| | P2 | Normal | 3,600 | 4,656 | ,449 | -6,183 | 13,383 |
| | | P1 | 5,900 | 4,656 | ,221 | -3,883 | 15,683 |
| | | P3 | -11,483(*) | 4,656 | ,024 | -21,266 | -1,700 |
| | | self | ,533 | 4,656 | ,910 | -9,250 | 10,316 |
| | P3 | Normal | 15,083(*) | 4,656 | ,005 | 5,300 | 24,866 |
| | | P1 | 17,383(*) | 4,656 | ,002 | 7,600 | 27,166 |
| | | P2 | 11,483(*) | 4,656 | ,024 | 1,700 | 21,266 |
| | | self | 12,017(*) | 4,656 | ,019 | 2,234 | 21,800 |
| | self | Normal | 3,067 | 4,656 | ,518 | -6,716 | 12,850 |
| | | P1 | 5,367 | 4,656 | ,264 | -4,416 | 15,150 |
| | | P2 | -,533 | 4,656 | ,910 | -10,316 | 9,250 |
| | | P3 | -12,017(*) | 4,656 | ,019 | -21,800 | -2,234 |
| Serious defects | Normal | P1 | ,350 | 3,722 | ,926 | -7,470 | 8,170 |
| | | P2 | -3,667 | 3,722 | ,338 | -11,487 | 4,153 |
| | | P3 | -4,183 | 3,722 | ,276 | -12,003 | 3,637 |
| | | self | -2,017 | 3,722 | ,595 | -9,837 | 5,803 |
| | P1 | Normal | -,350 | 3,722 | ,926 | -8,170 | 7,470 |
| | | P2 | -4,017 | 3,722 | ,295 | -11,837 | 3,803 |
| | | P3 | -4,533 | 3,722 | ,239 | -12,353 | 3,287 |
| | | self | -2,367 | 3,722 | ,533 | -10,187 | 5,453 |
| | P2 | Normal | 3,667 | 3,722 | ,338 | -4,153 | 11,487 |
| | | P1 | 4,017 | 3,722 | ,295 | -3,803 | 11,837 |
| | | P3 | -,517 | 3,722 | ,891 | -8,337 | 7,303 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | self | 1,650 | 3,722 | ,663 | -6,170 | 9,470 |
| | P3 | Normal | 4,183 | 3,722 | ,276 | -3,637 | 12,003 |
| | | P1 | 4,533 | 3,722 | ,239 | -3,287 | 12,353 |
| | | P2 | ,517 | 3,722 | ,891 | -7,303 | 8,337 |
| | | self | 2,167 | 3,722 | ,568 | -5,653 | 9,987 |
| | self | Normal | 2,017 | 3,722 | ,595 | -5,803 | 9,837 |
| | | P1 | 2,367 | 3,722 | ,533 | -5,453 | 10,187 |
| | | P2 | -1,650 | 3,722 | ,663 | -9,470 | 6,170 |
| | | P3 | -2,167 | 3,722 | ,568 | -9,987 | 5,653 |
| Diseases | Normal | P1 | 1,550 | 1,028 | ,149 | -,609 | 3,709 |
| | | P2 | ,233 | 1,028 | ,823 | -1,926 | 2,392 |
| | | P3 | ,250 | 1,028 | ,811 | -1,909 | 2,409 |
| | | self | 1,033 | 1,028 | ,328 | -1,126 | 3,192 |
| | P1 | Normal | -1,550 | 1,028 | ,149 | -3,709 | ,609 |
| | | P2 | -1,317 | 1,028 | ,216 | -3,476 | ,842 |
| | | P3 | -1,300 | 1,028 | ,222 | -3,459 | ,859 |
| | | self | -,517 | 1,028 | ,621 | -2,676 | 1,642 |
| | P2 | Normal | -,233 | 1,028 | ,823 | -2,392 | 1,926 |
| | | P1 | 1,317 | 1,028 | ,216 | -,842 | 3,476 |
| | | P3 | ,017 | 1,028 | ,987 | -2,142 | 2,176 |
| | | self | ,800 | 1,028 | ,446 | -1,359 | 2,959 |
| | P3 | Normal | -,250 | 1,028 | ,811 | -2,409 | 1,909 |
| | | P1 | 1,300 | 1,028 | ,222 | -,859 | 3,459 |
| | | P2 | -,017 | 1,028 | ,987 | -2,176 | 2,142 |
| | | self | ,783 | 1,028 | ,456 | -1,376 | 2,942 |
| | self | Normal | -1,033 | 1,028 | ,328 | -3,192 | 1,126 |
| | | P1 | ,517 | 1,028 | ,621 | -1,642 | 2,676 |
| | | P2 | -,800 | 1,028 | ,446 | -2,959 | 1,359 |
| | | P3 | -,783 | 1,028 | ,456 | -2,942 | 1,376 |
| Date of first flowerl | Normal | P1 | -5,500(*) | 1,893 | ,009 | -9,476 | -1,524 |
| | | P2 | -1,917 | 1,893 | ,325 | -5,893 | 2,060 |
| | | P3 | ,167 | 1,893 | ,931 | -3,810 | 4,143 |
| | | self | -6,833(*) | 1,893 | ,002 | -10,810 | -2,857 |
| | P1 | Normal | 5,500(*) | 1,893 | ,009 | 1,524 | 9,476 |
| | | P2 | 3,583 | 1,893 | ,075 | -,393 | 7,560 |
| | | P3 | 5,667(*) | 1,893 | ,008 | 1,690 | 9,643 |
| | | self | -1,333 | 1,893 | ,490 | -5,310 | 2,643 |
| | P2 | Normal | 1,917 | 1,893 | ,325 | -2,060 | 5,893 |
| | | P1 | -3,583 | 1,893 | ,075 | -7,560 | ,393 |
| | | P3 | 2,083 | 1,893 | ,286 | -1,893 | 6,060 |
| | | self | -4,917(*) | 1,893 | ,018 | -8,893 | -,940 |
| | P3 | Normal | -,167 | 1,893 | ,931 | -4,143 | 3,810 |
| | | P1 | -5,667(*) | 1,893 | ,008 | -9,643 | -1,690 |
| | | P2 | -2,083 | 1,893 | ,286 | -6,060 | 1,893 |
| | | self | -7,000(*) | 1,893 | ,002 | -10,976 | -3,024 |
| | self | Normal | 6,833(*) | 1,893 | ,002 | 2,857 | 10,810 |
| | | P1 | 1,333 | 1,893 | ,490 | -2,643 | 5,310 |
| | | P2 | 4,917(*) | 1,893 | ,018 | ,940 | 8,893 |
| | | P3 | 7,000(*) | 1,893 | ,002 | 3,024 | 10,976 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date of first pod | Normal | P1 | -7,167(*) | 1,967 | ,002 | -11,299 | -3,034 |
| | | P2 | -2,333 | 1,967 | ,251 | -6,466 | 1,799 |
| | | P3 | -2,167 | 1,967 | ,285 | -6,299 | 1,966 |
| | | self | -7,583(*) | 1,967 | ,001 | -11,716 | -3,451 |
| | P1 | Normal | 7,167(*) | 1,967 | ,002 | 3,034 | 11,299 |
| | | P2 | 4,833(*) | 1,967 | ,024 | ,701 | 8,966 |
| | | P3 | 5,000(*) | 1,967 | ,020 | ,868 | 9,132 |
| | | self | -,417 | 1,967 | ,835 | -4,549 | 3,716 |
| | P2 | Normal | 2,333 | 1,967 | ,251 | -1,799 | 6,466 |
| | | P1 | -4,833(*) | 1,967 | ,024 | -8,966 | -,701 |
| | | P3 | ,167 | 1,967 | ,933 | -3,966 | 4,299 |
| | | self | -5,250(*) | 1,967 | ,016 | -9,382 | -1,118 |
| | P3 | Normal | 2,167 | 1,967 | ,285 | -1,966 | 6,299 |
| | | P1 | -5,000(*) | 1,967 | ,020 | -9,132 | -,868 |
| | | P2 | -,167 | 1,967 | ,933 | -4,299 | 3,966 |
| | | self | -5,417(*) | 1,967 | ,013 | -9,549 | -1,284 |
| | self | Normal | 7,583(*) | 1,967 | ,001 | 3,451 | 11,716 |
| | | P1 | ,417 | 1,967 | ,835 | -3,716 | 4,549 |
| | | P2 | 5,250(*) | 1,967 | ,016 | 1,118 | 9,382 |
| | | P3 | 5,417(*) | 1,967 | ,013 | 1,284 | 9,549 |

Based on estimated marginal means
* The mean difference is significant at the ,05 level.
a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**Pairwise Comparisons**

| Dependent Variable | (I) Cv | (J) Cv | Mean Difference (I-J) | Std. Error | Sig.(a) | 95% Confidence Interval for Difference(a) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Upper Bound | Lower Bound |
| Dead Stems | O | R | ,133 | ,462 | ,776 | -,838 | 1,105 |
| | R | O | -,133 | ,462 | ,776 | -1,105 | ,838 |
| Dry matter | O | R | ,333 | ,340 | ,341 | -,382 | 1,049 |
| | R | O | -,333 | ,340 | ,341 | -1,049 | ,382 |
| Pod length | O | R | 3,220(*) | ,419 | ,000 | 2,339 | 4,101 |
| | R | O | -3,220(*) | ,419 | ,000 | -4,101 | -2,339 |
| N of Pods | O | R | 14,760 | 13,228 | ,279 | -13,031 | 42,551 |
| | R | O | -14,760 | 13,228 | ,279 | -42,551 | 13,031 |
| Fresh Weight | O | R | 510,267(*) | 176,524 | ,010 | 139,403 | 881,131 |
| | R | O | -510,267(*) | 176,524 | ,010 | -881,131 | -139,403 |
| Minor defects | O | R | -2,400 | 2,945 | ,426 | -8,587 | 3,787 |
| | R | O | 2,400 | 2,945 | ,426 | -3,787 | 8,587 |
| Serious defects | O | R | -1,740 | 2,354 | ,469 | -6,686 | 3,206 |
| | R | O | 1,740 | 2,354 | ,469 | -3,206 | 6,686 |
| Diseases | O | R | ,653 | ,650 | ,328 | -,712 | 2,019 |
| | R | O | -,653 | ,650 | ,328 | -2,019 | ,712 |
| Date of first flor | O | R | -2,967(*) | 1,197 | ,023 | -5,481 | -,452 |
| | R | O | 2,967(*) | 1,197 | ,023 | ,452 | 5,481 |
| Date of first pod | O | R | -1,567 | 1,244 | ,224 | -4,180 | 1,047 |
| | R | O | 1,567 | 1,244 | ,224 | -1,047 | 4,180 |

Based on estimated marginal means
* The mean difference is significant at the ,05 level.
a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**The date of first pod**

Duncan

| PortaEnx | N | Subset 2 | 1 |
|---|---|---|---|
| Normal | 6 | 40,5000 | |
| P3 | 6 | 42,6667 | |
| P2 | 6 | 42,8333 | |
| P1 | 6 | | 47,6667 |
| self | 6 | | 48,0833 |
| Sig. | | 0,276 | 0,835 |

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 11,606.
a Uses Harmonic Mean Sample Size = 6,000.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c Alpha = 0,05.