Master of Science
Mediterranean Organic Agriculture

Evaluation of pre-crops and fertilization on organic eggplant under Mediterranean conditions: case of Turkey

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Abstract

Organic agriculture feeds the soil by different operations which have their main effects generally on the long term. Organic practices, including crop rotation, are expected to enhance soil life and soil health. In this study, effects of different pre-crops (vetch, faba bean and broccoli) and fallow with two different fertilization strategies (compost tea and commercial fertilizer) on organic eggplant production and on soil fertility were evaluated. The main aim of the experiment was to identify the most suitable rotation program in organic farming for Turkey. Highest eggplant yield was obtained following vetch in pre-crop cycle and commercial fertilizer applied subplots. Results obtained during four years of the experiment were evaluated in respect to soil nitrogen (N), phosphorus (P), potassium (K) and organic matter (OM) content. Soil total N contents displayed an increase in all treatments in opposition to soil OM, P and K contents that showed a slight decrease over four years. Eggplant after faba bean fertilized with commercial fertilizer gave the highest gross margin due to higher total revenues.

Keywords: Organic agriculture, soil fertility, crop rotation, organic fertilizers, eggplant, gross margin
“for my family and loved ones...”
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Abbreviations

F: Fertilization treatments

P: Pre-crop treatments

C: Compost

CT: Compost tea or subplots fertilized with compost tea

CF: Commercial fertilizer Pow humus or subplots fertilized with commercial fertilizer

T0: The first soil sampling date after previous year’s main crop (pepper) and before the current year’s pre-crops

T1: Soil sampling date after the current year’s pre-crops and before the main crop (eggplant)

T2: Soil sampling date after 15 days from T1 soil analysis.

F.Bean: Faba bean

DM: Dry biomass

O.M: Organic matter

K: Potassium

P: Phosphorus

N: Nitrogen

GM: Gross margin

EC: Electrical conductivity

°C: Celsius

ppm: parts per million

g: gram

kg: kilogram

% = Percent

cm = centimeter

h = hour
INTRODUCTION

Organic practices, including crop rotation, are expected to enhance soil life and soil health. A basic rule of organic agriculture is that biological diversity and soil organic matter are drivers of productive organic farming systems (Mohler and Johnson, 2009).

Instead of using synthetic fertilizers, organic farmers use crop rotations, cover crops and compost to maintain or enhance soil fertility. Organic farmers employ biological, cultural, and physical methods to limit pest expansion and increase populations of beneficial insects (Delate, 2003).

Compost tea is another practice which has relatively faster and shorter effects than the other practices. Compost tea is described by Ingham (2002) as water extract of compost which contains soluble nutrients and diversity of bacteria, fungi, protozoa and nematodes.

A common research strategy - coordinated by the Mediterranean Agronomic Institute of Bari in the framework of its ‘Mediterranean Organic Agriculture’ Master program - was adopted by four institutes in Mediterranean countries, Turkey, Italy, Tunisia and Morocco. The aim is to develop agronomically, ecologically and economically suitable rotation programs. To achieve this aim, a four-year rotation program was initiated in 2006. In the second phase of the research, selected models will be tested for two years at farm level.

Objectives

The general objective of this work is to analyze the technical and economic feasibility of pre crops under two fertilization strategies (commercial fertilizer and compost tea) in open field on organic eggplant production under conditions prevailing in Izmir/Turkey. In the fourth year’s rotation plan, the objective was to analyze the tested crop rotation model for open field organic eggplant production. The specific objectives are enumerated as follows:

- to determine the effect of the tested treatments (soil building pre-crops and fertilization strategies) on organic eggplant plant growth, yield and fruit quality;
- to determine the effect of the tested treatments on soil fertility;
- to determine the effect of tested variables on weed, pest and disease incidence and,
- to conduct an economic analysis of eggplant production under tested site conditions and management practice.
Chapter 1: Literature Review

1. Soil Fertility

Soil fertility is a complex quality of soils that is the closest to plant nutrient management. It is the component of overall soil productivity that deals with its available nutrient status, and its ability to provide nutrients out of its own reserves and through external applications for crop production. It combines several soil properties (biological, chemical and physical) all of which affect directly or indirectly nutrient dynamics and availability. Soil fertility is a manageable soil property and its management is of utmost importance for optimizing crop nutrition on both a short-term and a long-term basis to achieve sustainable crop production (Roy et al., 2006).

Organic soil fertility management is guided by the philosophy of feed the soil to feed the plant. This basic philosophy is implemented through a series of practices designed to increase soil organic matter, biological activity, cycling and nutrient availability. Adding organic matters such as incorporating cover crop, crop residues and composts to cultivated soils over time builds soil organic matter and improves the ability of the soil to supply nutrients (Gaskell et al., 2007).

Organic farming systems rely on the management of soil organic matter to enhance the chemical, biological and physical properties of the soil, in order to optimize crop production (Watson et al., 2002). The foundation of organic farming lies in the health and fertility of the soil. A fertile soil provides essential nutrients to a growing crop plant and helps support a diverse and active biotic community. Strategies the transitional farmer will employ to build the soil are crop rotations, animal and green manures and cover cropping (VanTine and Verlinden, 2003).

Granstedt and Kjellenberg (1997) found that the organic treatments resulted in a higher soil fertility capacity and in crops with higher quality protein, higher starch content and a greater ability to tolerate stressful conditions and long-term storage in comparison with the inorganic treatments. On organic farms, where the importation of materials to build/maintain soil fertility is restricted, it is important that a balance between inputs and outputs of nutrients is achieved to ensure both short-term productivity and long-term sustainability (Kithlam, 2002).

Jaana and Marjo (1998) stated that the best soil structures and strongest wheat crops were found after clover leys and the poorest after peas. However, the most important determinant for the baking quality of the flour was the cultivar.
2. Crop Rotation

Crop rotation is the practice of planting a sequence of different crops and cover crops on a specific field. Crop rotations can be used to help build soil fertility, reduce insect pest pressure and suppress weeds (Eicher, 2003).

Crop rotation is a planned order of specific crops planted on the same field. However, crop rotation also means that succeeding crops are of different genus, species, subspecies or variety than the previous crop. Examples would be barley after wheat, row crops after small grains, grain crops after legumes etc. The planned rotation sequence may be for a two- or three-years or longer period. Some of the general purposes of rotations are to improve or maintain soil fertility, reduce erosion, reduce the build-up of pests, diseases and weeds, spread the workload, reduce risk of weather damage, reduce reliance on agricultural chemicals and increase net profit (Peel, 1998).

Crop rotation is an easy way to control diseases and insects at no cost. For example, tomato, cauliflower or cabbage planted in the same location each year will actually encourage build up of certain diseases in the soil. By rotating crops, thus removing the host plant, we prevent the spread of disease. Also, as overwintering insects emerge from the soil in the spring, they expect to find the same plant in the same place. By moving garden plants or weeds around, insect pests will have a harder time finding their target. Each crop has different fertilizer requirements. By changing the location of your crop you can avoid the risk of depleting the soil of specific nutrients. Some crops will actually add essential elements to the soil. By using a suitable crop rotation, you can actually build up the soil fertility over the years (Mayer, 2003).

Rotations are one dimension of the art and science of farm management. The biological principles of crop rotation intersect with many other aspects of the farm operation and farm business. Crop rotation is both a principle of production and a tool of management (Mohler, 2009).

According to Baldwin (2006) rotations are most effective when combined with such practices as manuring, composting, cover cropping, green manuring and short pasturing cycles. Together, these practices create soil quality improvements such as increased soil aggregate stability, decreased crusting of soil surfaces and increased granular structure and friable consistence. Rotations that include sod, pasture or hay crops also help to decrease bulk soil density, which can greatly impede root growth and nutrient flow. Simply by implementing management systems that maintain or increase soil organic matter there is the potential for increasing soil productivity for all cropping systems, including organic systems.
2.1. Green Manure

Green manures, often also considered as cover crops, are plants which are grown to improve the structure and nutrient content of the soil. They are a cheap alternative to artificial fertilizers and can be used to complement animal manures. Growing a green manure is not the same as simply growing a legume crop, such as beans, in a rotation. Green manures are usually dug into the soil when the plants are still young, before they produce any crop and often before they flower. They are grown for their green leafy material which is high in nutrients and protect the soil (HDRA, 1998).

Green manuring consists of ploughing in green, non-woody plants or plant parts. The plant material can come from a crop that was grown after or between the main crops or from a weed that grew during a fallow period. It can also come from a shade plant or tree whose cuttings or fallen leaves are suitable for ploughing into the soil. The goals of green manuring are to make nutrients available for the main crop; improve the soil structure; increase or retain the level of organic matter in the soil; increase the ability of the soil to retain moisture; and protect the soil against rain and wind erosion, dehydration and extreme temperature fluctuations at a time when no other crops are present. Additionally, when using leguminous plants as green manure, to: fix extra nitrogen out of the air, which becomes available to the main crop after the manure has been ploughed into the soil (Nieuwenhuis and Schöll, 2004).

Smallholder farmers can choose Green Manure (GM) legumes to improve poor soils that are not suitable for the production of food crops. In the Republic of Bénin, these potential GM niches were found in non-sandy areas, where land is moderately available, i.e., scarce enough to impose a shifting cultivation based on soil fertility taxonomy (Akouègnon et al., 2008).

The green-manure is able to improve the availability of nitrogen for cash crops in succession even in the absence of fertilization. The effect of the distribution of organic fertilizer was not efficient in comparison to green-manure, showing small increases of production even at the highest level (Mazzoncini et al., 2008).

Migliorini and coworkers (2008) showed that the maintaining of soil fertility is very important in organic farms. Green manure usage represents a viable and important practice and the correct choice of the suitable crops for the local conditions is a crucial factor in order to obtain sufficient biomass quantity and nutrient availability.

Green manures are important to add to the diversity and are used in organic farming systems to reduce soil N losses, help crops out-compete weeds and to improve soil structure and organic matter levels. Green manures also provide an important ground cover function to prevent soil erosion and minimize nutrient losses (Briggs, 2008).
3. Fertilization

3.1. Compost

Composting of organic waste represents an important and well established part of waste management in Europe. In recent years, anaerobic treatment of organic waste materials and production of nonfossil energy have been promoted and thus, production of digestate and press water (i.e. the products from liquid/solid separation of the fermenters output) has increased (Fucks et al., 2008).

Libbey (2000) found that for broccoli production, the addition of compost as a soil amendment should not be confused with a synthetic fertilizer addition. The long-term benefits of compost to the soil-plant system in terms of improving soil structure through the addition of organic matter, soil moisture retention and soil microbial activity may exceed benefits derived from the supply of plant nutrients alone. A study of the long term effects of compost addition and varying rates and types of compost would prove beneficial to organic farmers in choosing the optimum conditions for organic vegetable and herb production.

3.2. Compost Tea

Compost tea is produced by putting a defined quantity of compost into water and mixing it for a definite time. Actively aerated compost teas with additives are recommended to be produced and expected to enhance the growth of beneficial and suppress pathogenic micro-organisms. (Ingham, 2003)

Compost tea describes many different preparations made using compost as a starting material and producing a liquid extract or in some cases a “liquid version” of the original compost. Compost tea like compost itself has the potential to be a powerful tool for agriculture. Compost teas are applied either to the soil or to the plant foliage. Those applied to the soil will move into the root zone and affect the rhizosphere of the plant. Nutrients carried in the tea will be used by the plant as well as the microorganisms in the soil. The microbes in the compost tea may have a lot of competition with other soil microorganisms, but have the opportunity to become a part of the soil and rhizosphere microbial ecology (Bess, 2000).

Ryan (2003) cited that Compost tea offers some of the benefits of compost in a more manageable package. For centuries, farmers have soaked “tea bags” full of compost in tubs of water, and then used the resulting liquid (compost tea) to fertilize and improve the health of their crops. This type of compost tea commonly referred to as “passive compost tea”, typically uses a ratio of one part compost to five parts water and steeps for about two weeks before it is applied to crops as a soluble nutrient solution.
Compost tea is a readily available form of compost that will impact the plant more quickly than compost mixed into the soil. Compost quality issues, including maturity and microorganism content, become very important for making effective compost tea. The transformation of compost into compost tea cannot improve the original quality of the compost (Bess, 2000).

4. Information about Pre Crops and Main Crops

4.1. Vetch

Common vetch (\textit{Vicia sativa} L.) is an annual legume cultivated under rain-fed conditions in the semi-arid regions of Mediterranean countries. In these areas, vetch is integrated into the conventional cereal-fallow crop rotation system. This species helps alleviate seasonal forage deficits and therefore contributes to the economic sustainability of cereal-sheep farming systems (Rebolé \textit{et al.}, 2004).

Common vetch (\textit{Vicia sativa} L.) is the most important legume used for fresh and dry fodder production in Turkey. It has an important role in crop rotation prior to wheat. Cereals are also important contributors to animal feeding in Turkey, both as grain and forage. Cereals grown in the Aegean region are capable of high yields owing to many years of plant breeding and optimization of cultural practices. The incorporation of legumes in forage mixtures with grasses or cereals is an important and well-established practice in some regions of Turkey. Furthermore, oat, barley, wheat and triticale are added to provide a climbing frame for the legumes and to increase the bulk of feed produced (Tuna and Orak, 2007).

Common vetch is used as a cover crop, green manure, pasture, sillage and hay. Its high dry matter and nitrogen accumulation and the absence of hard seeds, make it an excellent winter leguminous cover crop in annual vegetable rotations. When planted alone, it can provide substantial amounts of N to the following crop (Sattel \textit{et al.}, 1998).

4.2. Broccoli

Broccoli is a cool weather plant. It has more vitamins than any other vegetable. They grow one large head and often several smaller side shoots. Broccoli prefers a well-drained soil. Optimum soil temperatures range for germination is between 12.5 and 24 °C (Kovatch, 2003).

Spear size is the main commercial character in broccoli, and plant density is the most important factor affecting yield if yield is expressed on an area basis. Competition between broccoli plants greatly affects spear weight; which can be adjusted to the requirements of different markets by manipulating plant density (Francescangeli \textit{et al.}, 2006).
Tourte and friends (2004) researched that the crop yield in their study is 650 twenty-two pound boxes or 7.15 tons per acre, which takes into account, the 5% acreage dedicated to the insectary planting. The typical yield range is 500 to 900 boxes per acre. Like conventionally produced crops, yields for organically produced crops can vary depending on site and growing conditions. In some situations, and in years with high pest populations, organic yields may be lower than conventional yields because of fewer treatment options. Conversely, when growing conditions are optimal, and pest pressure is low, organic yields can be similar or the same as those in conventional management.

4.3. Faba Bean

This annual legume grows best under cool, moist conditions. Hot, dry weather is injurious to the crop, so early planting is important. The time from seeding to harvest ranges from 80 to 120 days. Faba beans should be grown only once every four years in the same field to avoid a build-up of soil-borne diseases. Their susceptibility to diseases which are common in rapeseed and in sunflower limits their place in a crop rotation with other specialty crops (Oplinger et al., 2010).

Faba bean adds a large amount of organic matter to the soil when turned in as green manure (McLeod, 1982). The best time for incorporation is at blossom (McLeod, 1982; Munoz and Graves, 1988). The vegetation will decompose more rapidly if the plants are succulent, but in general, bell bean residue persists longer than that of other leguminous cover crops, which can help improve heavy soils (Miller, 1988).

Faba bean is a crop well adapted to the Mediterranean environment (Newton and Hill, 1977; Dantuma and Thomson, 1983). Its performance varied from season to season as well as from location to location (Hebblethwaite et al., 1983). The crop is very sensitive to competition from both broad-leaved and grassy weeds (Glasgow et al., 1976; Lawson and Wiseman, 1978).

Faba bean plays an important role in farming systems of the countries around the Mediterranean Sea. Besides being an important food crop, it contributes to feed and fodder supply for livestock and affect positively the soil productivity for the cereal crops growing in rotation through improving the productivity in physical, chemical and biological properties of the soil (Saxena, 1991).
4.4. Eggplant

Eggplant is a very popular native vegetable in Asia and the Mediterranean basin. In 2003, eggplant world production was 29 million tons (t) from 1.6 million hectares. The average yield (18 t/ha) is extremely variable, depending on climate, cultural system, crop duration and grower technology. (Frary et al., 2007)

Eggplant prefers a soil that is deep, fertile, well drained, high in organic matter, and has a pH of 5.5 to 6.8. A sandy loam soil is ideal when an early yield is desired (Chen, 2002).

Eggplant is damaged by frost and low temperatures. To produce high yields of good quality fruit, it needs five months of warm to hot weather, with temperatures varying between 21 to 30°C (Burt, 2005).

Eggplants are usually planted in the field as seedlings. The seedlings are purchased from commercial nurseries and need to be ordered at least 10 weeks before planting. Transplant seedlings need to have 6–7 leaves and be 10–12 cm high (Ullio, 2003).

Eggplant need uniform soil moisture conditions for high production. Dry periods may cause shedding of flowers and young fruits (Burt, 2005).

Eggplant is a long duration crop, with high yields which remove large quantities of plant nutrients. An eggplant crop yielding about 60 t/ha of fruit removes 190 kg N, 10.9 kg P and 128 kg K (Gnanakumari and Sathyanarayana, 1971). Nutrient uptake in eggplant partly depends on the source of nutrients (Jose et al., 1988).

Nutrient supply to crops depends on the use of legumes to add nitrogen to the system and limited inputs of supplementary nutrients, added in acceptable forms. Manures and crop residues are carefully managed to recycle nutrients around the farm. Management of soil organic matter, primarily through the use of short-term leys, helps ensure good soil structure and biological activity, important for nutrient supply, health and productivity of both crops and livestock. Carefully planned diverse rotations help reduce the incidence of pests and diseases and allow for cultural methods of weed control (Watson et al., 2002).

Blossom end rot is very important for eggplant. At first glance; damage from this disorder may not be obvious. However, home gardeners can be frustrated and distressed when they notice dry sunken decay developing on the bottom, or blossom end (opposite the stem), of the picked fruit of affected plants. Fruit may be affected throughout the season, but the first fruit produced in a season are often most severely affected (Draper et al., 2002).
Phomopsis blight is caused by the fungus *Phomopsis vexans*, and is a major disease of eggplant. Phytophthora blight can quickly destroy eggplants. Plants will get dark streaks prior to collapsing and dying. The disease occurs when spores are released from a fungal fruiting body (pycnidia) and dispersed by splashing rain, insects, and contaminated equipment. Spores germinate rapidly when free moisture is present on leaves, stems, or leaves. The fungus survives between eggplant crops on and in crop debris, seeds, and soil (Schwartz and Gent, 2007).

First harvest of eggplants begins 65 to 90 days from transplanting. Eggplants should be harvested when the fruit surface is glossy and tender and before seeds within the fruit become brown (Lewis, 2005). Eggplants can yield 30-40 ton/ha. Eggplants are tender and should be handled carefully (Duman and Kaya, 2010).
Chapter 2: Material and Methods

1. Experimental Site

1.1. Farm Location and History

The study is conducted at the experimental field of Faculty of Agriculture, Horticulture Department Ege University Campus in Izmir / Turkey. The site is 40 m above the sea level and located at Latitude: 38° 027´15.4`` N and Longitude: 27013´26.3`` E (GPS, Garmin 12). A general view of the experimental field can be seen in Figure 1.

Figure 1. General view of the experimental field.

Prior to the initiation of the experiment, the field was a cherry collection orchard that was later uprooted. No fertilizer or pesticides were applied since 2002. The four year experiment is summarized as follows Table 1.
Table 1. Four year experimental plan for Turkey

<table>
<thead>
<tr>
<th>Pre-crops</th>
<th>Fertilization</th>
<th>Main crops</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vetch</td>
<td>C</td>
<td>Tomato</td>
<td>2006-2007</td>
</tr>
<tr>
<td>Faba Bean</td>
<td>CT</td>
<td>Zucchini</td>
<td>2007-2008</td>
</tr>
<tr>
<td>Broccoli</td>
<td>CF</td>
<td>Pepper</td>
<td>2008-2009</td>
</tr>
<tr>
<td>Fallow</td>
<td>CT</td>
<td>Eggplant</td>
<td>2009-2010</td>
</tr>
<tr>
<td></td>
<td>CF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.2. Climatic Conditions

The region is characterized by a Mediterranean climate with dry summers followed by mild and rainy winters. In Izmir, precipitation is distributed as 22% in spring, 2% in summer, 21% in autumn and 55% in winter. The average rainfall is reported by The Turkish State Meteorological Service as 689 mm for the last 70 years, and 745.0 mm in 2006, 478.0 mm in 2007, 427.3 mm in 2008, 1071.7 mm in 2009 and 583.5 mm till the end of August, 2010. As could be seen in Table 2, there are significant monthly and yearly fluctuations in the amount of rain received.

Table 2. The monthly average rainfall (mm) received between 2006 and 2010.

<table>
<thead>
<tr>
<th>Months</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>77.5</td>
<td>33.1</td>
<td>30.1</td>
<td>204.1</td>
<td>142.3</td>
</tr>
<tr>
<td>February</td>
<td>93.4</td>
<td>22.6</td>
<td>9.0</td>
<td>165.2</td>
<td>301.3</td>
</tr>
<tr>
<td>March</td>
<td>180.9</td>
<td>29.7</td>
<td>60.0</td>
<td>175.7</td>
<td>16.1</td>
</tr>
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<td>62.3</td>
<td>83.8</td>
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<td>44.3</td>
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<td>92.6</td>
<td>160.3</td>
<td>-</td>
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<td>118.8</td>
<td>101.0</td>
<td>151.8</td>
<td>-</td>
</tr>
</tbody>
</table>
1.3. Soil Properties

According to the results of the analysis at T0 in 2006-2007 (sampling done before pre-crops), the texture of the soil is loamy. Soil pH is 7.78 and salinity is 0.047. The soil is rich in nitrogen and phosphorus, high in calcium, iron, magnesium and zinc and adequate in copper and manganese.

1.4. Experimental Design

Figure 2. Experimental design for pre-crops.

The experimental design is a split-plot design with four replicates and two factors. The main factor is the pre-crops compared to weeded fallow as control. The second factor is the fertilization strategy applied to the main crop. Two fertilization strategies are tested addition of Compost tea extracted from commercial compost (CT) and commercial organic fertilizer (CF). The composition of compost and commercial fertilizer are given in Table 4, respectively.

Each sub-plot is 30 m² and the distance between sub-plots is 1m to create a buffer (Figure 2).
1.5. Cultural Practices

All the soil-related cultural practices were kept at minimal level not to disturb the soil fauna. First disk harrowing was done before the pre-crops to prepare the field on October 23, 2009. On December 09, 2009 chisel harrowing were performed - except broccoli plots - to prepare the soil for seeding faba bean and vetch. To incorporate the pre-crops and prepare the soil for eggplant seeding, soil was ploughed on April 30, 2010 and disk harrowed on May 2, 2010.

1.5.1 Irrigation

The experimental plots were irrigated by a drip irrigation system in order to have homogeneity in water distribution (Figure 3). During the pre-crop growth cycle broccoli plants were irrigated only once with 1.6 m$^3$ of water. Other plots were not irrigated as there was enough rain during the vegetation period of pre-crops. During eggplant production, the field was irrigated regularly from May 15 to September, 2010 growth period.

Figure 3: View of drip irrigation system in the field

1.5.2. Plant Protection

Weed control was done by hoeing to minimize the adverse effect on soil fauna and to minimize the carbon emission. Weeding was done once for broccoli plots on January 9, 2010. Faba bean plots were weeded only once on January 25, 2010.

Eggplant plots were weeded only once on June 16, 2010. For pest and disease control, preparations permitted in organic agriculture were used against red mite during eggplant production when necessary (as mentioned in Table 3).
Table 3. Plant protection measures applied in eggplant production.

<table>
<thead>
<tr>
<th>Date of application</th>
<th>Targeted organism</th>
<th>Application</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.06.2010</td>
<td>Red Mite</td>
<td>Powder Sulphur</td>
<td>400 g/100 l</td>
</tr>
<tr>
<td>06.07.2010</td>
<td>Red Mite</td>
<td>Powder Sulphur</td>
<td>600 g/150 l</td>
</tr>
</tbody>
</table>

2. Plant Material

2.1. Pre-crops

Three pre-crops were tested: Faba bean (*Vicia faba*) as commercial legume, common vetch (*Vicia sativa*) as incorporated legume and broccoli (*Brassica oleracea* var. *italica*) as farmers’ choice. The fourth treatment was fallow used as control.

Untreated conventional faba bean seeds were purchased, and organic broccoli seedlings were provided by Ege Fide/İzmir. Organic vetch seeds were provided from Menemen Research Institute/İzmir. Common vetch seeds were directly sown (10 g seed.m$^{-2}$) on December 9, 2009. Broccoli seedlings were transplanted (5 seedlings.m$^{-2}$) on October 26, 2009 and faba bean seeds were sown (12.5g seed.m$^{-2}$) on December 9, 2009 to the field.

Incorporation was done on April 30, 2010 all treatments which coincided with the end broccoli production and at 2/3 of flower opening of common vetch.

2.2. Main Crop, Eggplant (*Solanum melongena*)

Aydin Siyahi variety of eggplant was used as the main crop. Organically grown seedlings, provided by Ege Fide/İzmir were planted on May 15, 2010 after incorporation of the pre-crops. Plant density of eggplant was 36000 seedlings.ha$^{-1}$. Harvests were done between July 6 and August 25, 2010
3. Fertilization program

Nutrition of eggplant was maintained by applying commercial compost (Bioaktif) both as compost and compost tea and a commercial fertilizer (Powhumus) (Table 4). Bioaktif is produced by Camli Besi Company, Izmir, Turkey. Powhumus produced by Humintech, Germany is imported by IZOTAR Company, Izmir, Turkey and is permitted for use in organic agriculture according to Annex II of regulation (EEC) 2092/11 and the Turkish regulation on organic agriculture.

Bioaktif, as compost was applied at a rate of 2000 kg.ha$^{-1}$ to all subplots prior to eggplant planting. Further to compost application, compost tea was applied to compost tea subplots on five different dates (as July 14-21-28 and August 5-12, 2010) for a total amount of 7812 l.ha$^{-1}$. Powhumus was applied to commercial fertilizer subplots on different dates (July 21-28 and August 5-12, 20010) for a total amount of 6.9 kg.ha$^{-1}$. Both fertilizations were done by drip irrigation.

<table>
<thead>
<tr>
<th>Table 4: Composition of organic compost ‘Bioaktif’ and Pow humus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bioaktif</strong></td>
</tr>
<tr>
<td>Total nitrogen</td>
</tr>
<tr>
<td>Organic nitrogen</td>
</tr>
<tr>
<td>Total P$_2$O$_5$</td>
</tr>
<tr>
<td>Total soluble K$_2$O</td>
</tr>
<tr>
<td>Total organic matter</td>
</tr>
<tr>
<td>Humidity</td>
</tr>
<tr>
<td>pH</td>
</tr>
<tr>
<td>Total Potassium humate</td>
</tr>
<tr>
<td>Humic Acid</td>
</tr>
<tr>
<td>Fulvic Acid</td>
</tr>
</tbody>
</table>

3.1. Compost Tea Extraction

Compost tea was prepared from the commercial compost, Bioaktif, in plastic tanks (in order to avoid any air contamination from insects or dust) under aerobic conditions according to the protocol stated below:

- Water compost ratio: 2:5:1 (v/v) as recommended for making a compost extract (Brinton et al., 2004),
- Aeration: Continuous aeration through an air pump used in aquariums,
- Temperature: 24°C (± 5), recommended condition for micro organisms' growth,
- Duration of tea extraction: 2 days,
• Applied directly without storing.

CT was analyzed to determine the major properties of the applied extract. Two representative samples were taken during the application period for chemical analysis and average values were calculated. Average nitrogen content of compost tea was 0.11%, pH was 8.36 and EC was 11.64 ms/cm.

4. Sampling

4.1. Soil

Soil samples were taken before planting/sowing soil building crops after the decomposition of the previous main crop, on October 24, 2009 (T0). The second sample (T1) was taken two days before incorporation of pre-crops on April 28, 2010. The third sample (T2) was taken after 15 days of T1 on May 13, 2010. Samples were taken at 0-30 cm depth. Two different soil depths were sampled during the third sampling: 0-30 cm and 30-60 cm to obtain the nutrients in different soil depth. They were taken from five different places in each subplot following the "V" system. The samples were analyzed at Ege University, Faculty of Agriculture Soil Science Department.

4.2. Plant Performance

Presence of any physiological damages on the plants was monitored by observations. For analyses, three healthy and representative broccoli plants, five faba bean plants and three eggplant plants were selected. In vetch and fallow plots sampling was done by throwing five times in each subplot a square frame (25x25cm) randomly and taking the plants inside the square without breaking the integrity of the plants (including roots).

4.3. Quality

Five faba bean plant samples were taken on April 8, 2010 from each subplot for determination of fresh and dry biomass. Twenty five faba bean pods were also taken from each subplot for quality analysis. Diameter (mm), weight (g), length (mm), grain (seed) number of pods and dry matter (%) were analyzed (Figure 4).

For broccoli, three representative plant samples were taken from each subplot on March 31, 2010 for dry and fresh weight of root, leaf and stem and total weight of plants (g).

For eggplant, ten representative fruit samples were taken from each subplot on two different dates 19.07.2010 and 17.08.2010 which is between first harvest date and last harvest date for quality assessment.
4.4. Spontaneous Vegetation

All the collected data related to plant number and species for each subplot were presented as follows: Number of plants collected from each subplot, species number and percentage for each species are calculated for each of treatments separately (during pre-crop cycle and main crop cycle).

Two samplings were done, the first March 9, 2010 for pre-crops and the second one on June 22, 2010 during the main crop.

Square frames of 25 cm² were thrown five times in each subplot (corresponding to a total sampled surface of 1.2 m² for each treatment) to have 1% of sampled surface in respect to the whole experimental area. Each time the square frame was thrown; it was pushed downward and laid on the soil. All plants within the frame were counted according to species and carried in bags to preserve plant integrity (not simply cut). Number of plants and species was determined and recorded in excel sheets.
5. Methods

5.1. Soil Analysis

Before analysis each soil sample was spread on trays and air-dried, then thoroughly mixed and rolled in a mortar to break up clods, and finally screened through a 2 mm mesh sieve.

The mechanical analysis for particle size was carried out by the hydrometer method using sodium hexametaphosphate as a dispersing agent according to Chapman and Pratt (1961) and the soil texture was determined based on the ratio of soil particles.

Soil pH was determined in 1:2.5 soil water (weight/volume) suspensions using a glass electrode pH – meter (Rhoades, 1982).

Soil organic matter content was analyzed by means of the Walkley and Black method (Jackson, 1967). Carbon content was calculated by applying the following formula: Carbon (%) = Organic matter (%) / 1.724

Available N was determined by shaking 10 g of soil with 100 ml of K₂SO₄ for one hour. An aliquot of 50 ml of the filtered extract was subjected to steam distillation with MgO and Devarda alloy to determine N according to the procedure described by Keeny and Nelson (1982). Available phosphorus was determined by shaking 5 g of soil with 100 ml of NaHCO₃ 0.5 M for 1 hour; pH was adjusted to 8.5. Phosphorus was determined in 10 ml of the filtered extract colorimetrically by spectrophotometer using the stannous chloride method described by Jackson (1958). Sodium and potassium was determined using flame photometer according to Black et al. (1982). Calcium and magnesium were found by titration with versenate method, using ammonium purpurate as an indicator for calcium and eriochrome black T as an indicator for calcium and magnesium according to U.S.S.L. (1954).

5.2. Plant Analyses

Plant samples of faba bean, broccoli and eggplant were separated into different parts as leaves, stems and roots and weighted separately.

Samples were cut into small pieces, spread out in single layers and dried at 65°C for five days (Nyabundi and Hsaio, 1989), and then the weight was recorded to assess the dry matter weight. Dry matter content is calculated as follows: DM = (Dry weight / Fresh weight) *100.

Moisture content (%) is calculated by subtracting DM from 100.
5.2.1. Yield

Heads of broccoli were not marketable due to low quality. For faba bean, yield at each harvest was recorded both as weight and as number of fruits. Eggplant fruits were harvested two or three times a week. Each harvest was recorded as total yield (kg), weight (g) and number of fruits for each subplot and the total production per plant.

5.2.2. Quality

Weight (g), length (cm), diameter (mm) and seed number of faba bean pods were measured. For eggplant, the amount of fruit in marketable and non-marketable quality classes was determined both as number and weight. Weight (g), width (cm) and length (cm) of eggplant fruit was measured with a digital compass. A Nippon FHR-1 penetrometer possessing a conical tip (base diameter 12 mm and length 10 mm) was used to measure firmness, and results were expressed in Newton (N).

5.3. Economic Analysis

To complement the agronomic research work, economic evaluation associated to the different rotation programs and fertilization strategies was performed. For this purpose, the Gross Margin (GM) was calculated for each of the eight tested treatments. Each calculated value represents the average of values collected from the four replications for each treatment. Difficulties related to the calculation of fixed costs under experimental conditions and in different countries led to consider the gross margin instead of the whole-farm budget calculation in the economic evaluation. It is noteworthy to mention that the gross margin is conventionally used for research in agricultural economy. Data were elaborated by calculating the average of variable costs (input, labor and machine costs) and gross income (output, yield) of each treatment according to the following equation:

\[ \text{GM} = \text{gross revenue (total gross income)} - \text{total variable costs} \]

(Kay and Edwards, 1999).

Data collection was carried out throughout the experimental period and records were taken for all the agronomic operations. For this purpose, an opposite excel sheet was used for each treatment.

5.4. Statistical Analysis

Analysis of variance was done using the statistical analysis program SPSS V16.
Chapter 3: Results and Discussion

1. Climatic Conditions

Climatic conditions prevailing at the experimental site in İzmir-Turkey display a typical Mediterranean climate with warm and rainy winter and hot and dry summer. Figure 5 shows that monthly average rainfall and relative humidity during the experiment.

![Climatic Conditions Chart]

Figure 5. Monthly average rainfall (mm) and relative humidity during the experiment.

As could be seen in Figure 5, the growth cycle of the pre-crops (October 2009-April 2010) coincided with the rainy period. Precipitation during the pre-crop growth cycle totaled to 818.5 mm starting from November 2009 till the end of February 2010, precipitation was much higher than the previous years and eventually it affected the growth and yield parameters of pre-crops and soil nutritional status.

Humidity levels increased till the middle of November 2009 and later it constantly decreased during spring and summer of 2010. Relative humidity remained around 50% during the main crop cycle.
Figure 6 shows the monthly maximum, minimum and average temperatures (°C) during the experiment.

During the pre-crop cycle growth, temperatures decreased constantly from October ($T_{\text{average}} = 20.8^\circ C$) to January ($T_{\text{average}} = 10.6^\circ C$), and afterwards they started increasing constantly especially after March. During legumes cycle, average temperature was 14.6°C which is very favorable for faba bean growth as it prefers average temperatures ranging from 15 to 20°C for the best growth (Costa et al., 1997).

Conditions were arid at the initial stage, so broccoli plots were irrigated. However, further on the prevailing adverse conditions (heavy rainfall limited amount of light and lower temperatures) suppressed broccoli growth. Francescangeli et al., (2006) report that light is an important environmental factor affecting crop development and growth in broccoli. Average temperature was 14.6 °C during the pre-crop cycle which is rather low for broccoli since it prefers average temperatures of 18° to 25°C for best growth (Smith and Doubrava, 2003).

During the main crop cycle spring - summer 2010, climatic conditions were favorable for eggplant production. There were constant increases in both maximum and minimum temperatures. Average temperatures fluctuated between 21.8 °C and 30.2 °C (Figure 6).
2. Soil Properties

2.1. Nutritional Status during 2009-2010 Cycles

As could be seen in Table 5, after the completion of pepper (as the main crop in the previous year) which has a strong tap root and an efficient absorbing system going up to 90 to 120 cm (Weaver and Bruner, 1927) harvest and incorporation of pepper plants (T0), soil nutritional status of the tested variables did not show any statistically significant effect in respect to soil total nitrogen, available phosphorus, available potassium and organic matter. Although statistically significant differences did not appear, the N content was highest in faba bean plots and lowest in the vetch plots (Table 5). In respect to K, faba bean had the highest levels which could be also attributed to the fact that grain legumes increase the potassium availability (Erik, 2004).

Table 5: Statistical analysis of soil macro nutrient and organic matter contents of the soil sampled at T0 and T1 for different treatments.

<table>
<thead>
<tr>
<th>Pre-crops (P)</th>
<th>Fertilization Program (F)</th>
<th>N (%)</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
<th>Organic Matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T0</td>
<td>T1</td>
<td>T0</td>
<td>T1</td>
<td>T0</td>
</tr>
<tr>
<td>Fallow</td>
<td>CT</td>
<td>0.11</td>
<td>0.11</td>
<td>13.55</td>
<td>3.65</td>
</tr>
<tr>
<td></td>
<td>CF</td>
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<tr>
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<tr>
<td>F.Bean</td>
<td>CT</td>
<td>0.11</td>
<td>0.12</td>
<td>15.60</td>
<td>3.22</td>
</tr>
<tr>
<td></td>
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<td>0.13</td>
<td>13.03</td>
<td>6.04</td>
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<td></td>
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<td>0.12</td>
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<td>5.04</td>
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<tr>
<td>Mean</td>
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<td>0.11</td>
<td>0.12</td>
<td>13.25</td>
<td>5.54a</td>
</tr>
<tr>
<td>Broccoli</td>
<td>CT</td>
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<td>0.11</td>
<td>14.70</td>
<td>3.62</td>
</tr>
<tr>
<td></td>
<td>CF</td>
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<td>0.11</td>
<td>12.48</td>
<td>2.52</td>
</tr>
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<td>Mean</td>
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<td>0.11</td>
<td>13.59</td>
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<td>Mean CF</td>
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<tr>
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<tr>
<td>P</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>*</td>
<td>ns</td>
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<tr>
<td>PxP</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns: not significant
* statistically significant at 0.05 level
** statistically significant at 0.01 level

The effect of the tested pre-crops and the fertilization types did not show significant effect on soil nutritional status after the incorporation of pre-crops (T1) in respect to total nitrogen, available potassium and organic matter as at T0 (Table 5). Even though the difference was not significant statistically, the highest nitrogen content was obtained at T1 after vetch and the lowest one
was after incorporation of faba bean. Higher nitrogen levels anticipated with faba bean was not obtained. Probably heavy rainfalls prior to the rapid growth of faba bean plants caused leaching of nitrogen from the subplots and furthermore taken up and removed by the harvested faba bean pods that are known to contain 25 to 35 % protein (Larralde and Martinez, 1991). McLeod (1982) also reports that faba bean supplies more organic matter if turned in as green manure at blossom stage. The differences between tested pre-crops were significant at 5 % level. Vetch as a soil building crop improved soil organic matter and especially phosphorus contents. Karađag and Büyükburç (2001) report that high soil P increases nodule numbers on the main and especially lateral roots of vetch resulting in higher biomass. Favorable conditions for common vetch improved biomass and, thus, incorporated amount of organic matter and P with vetch.

The following figure shows the evolution of soil O.M, total N, available K and available P from T0 to T2

![Evolution of soil O.M, total N, available K and available P from T0 to T2](image)

**Figure 7.** Evolution of soil O.M, total N, available K and P from T0 to T2

The average soil organic matter, total nitrogen, available K and available P varied among three sampling dates, T0 (after incorporation of main crop and before pre-crops), T1 (after incorporation of pre-crops) and T2 (2 weeks after incorporation of pre-crops). Soil organic matter and available phosphorus contents decreased significantly from T0 to T2 whereas the change in soil total N and K contents were not statistically significant.

The use of adequate organic and mineral fertilization ranks among the most important requirements for eggplant production, and is necessary to meet the plant high nutritional demand mainly for nitrogen (N) and phosphorus (P), especially in low-fertility areas (Filgueira, 2003).
2.1.1. Effect of Soil Depth

Table 6 displays the major constituents at two soil depths sampled at T2. Neither pre-crops nor fertilization strategies had marked effect on soil N, P, K or organic matter contents except in the case of pre-crops on soil available K (5% significance). Vetch provided the highest soil K at T1. Fallow and faba bean were grouped together and broccoli plots were in between these two statistical groups.

The top soil (0-30 cm) is rich especially in respect to soil K and organic matter content compared to 30-60 cm depth. The tested pre-crops have rather shallow root systems. Faba bean has a taproot with widespread roots at 30 cm (Anonymous, 2010). Manschadi et al., (1998) confirm that 60% of faba bean roots are in the soil (15 cm). Common vetch is more effective at the top soil with higher number of nodules enriching N content of the top soil by 52% (Thorup Kristensen, 2001; Karadağ and Büyükbürç, 2001). Broccoli compared to vetch and faba bean has a deeper effective rooting depth of 0.30 to 0.46 m. However, the length of the growth period affects also the root growth and the nutrient uptake (Gutezeit, 2004). Precrops and natural vegetation are all incorporated at a depth of 15 to 30 cm. Thus, even if all pre-crops and natural vegetation uptake nutrients mostly from the top soil, their incorporation improve nutrient supply in this layer.

Table 6: Soil macro nutrient and organic matter content of the soil sampled at two different depths (0-30 and 30-60) at T2.

<table>
<thead>
<tr>
<th>Pre-crops</th>
<th>Fertilization Program</th>
<th>N (%)</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
<th>Organic Matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-30 30-60</td>
<td>0-30 30-60</td>
<td>0-30 30-60</td>
<td>0-30 30-60</td>
<td>0-30 30-60</td>
</tr>
<tr>
<td>Fallow</td>
<td>CT</td>
<td>0.13 0.09</td>
<td>4.9 4.2</td>
<td>288.8 249.8</td>
<td>1.28 0.65</td>
</tr>
<tr>
<td></td>
<td>CF</td>
<td>0.13 0.14</td>
<td>5.3 5.2</td>
<td>303.1 215.8</td>
<td>1.31 0.72</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.13 0.12</td>
<td>5.1 4.7</td>
<td>295.9b 232.8</td>
<td>1.29 0.68</td>
</tr>
<tr>
<td>F.Bean</td>
<td>CT</td>
<td>0.13 0.10</td>
<td>6.8 4.6</td>
<td>303.1 225.5</td>
<td>1.06 0.48</td>
</tr>
<tr>
<td></td>
<td>CF</td>
<td>0.12 0.10</td>
<td>4.7 4.9</td>
<td>271.6 206.1</td>
<td>1.10 0.25</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.13 0.10</td>
<td>5.8 4.7</td>
<td>287.4b 215.8</td>
<td>1.08 0.36</td>
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<tr>
<td>Vetch</td>
<td>CT</td>
<td>0.13 0.27</td>
<td>4.5 4.5</td>
<td>351.6 230.4</td>
<td>1.86 0.42</td>
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<tr>
<td></td>
<td>CF</td>
<td>0.14 0.12</td>
<td>5.2 5</td>
<td>358.9 259.5</td>
<td>1.56 0.68</td>
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<tr>
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<td>0.14 0.19</td>
<td>4.9 4.8</td>
<td>355.3a 244.9</td>
<td>1.71 0.55</td>
</tr>
<tr>
<td>Broccoli</td>
<td>CT</td>
<td>0.13 0.11</td>
<td>4.7 3.9</td>
<td>316.9 247.4</td>
<td>0.67 0.65</td>
</tr>
<tr>
<td></td>
<td>CF</td>
<td>0.13 0.11</td>
<td>4.5 2.6</td>
<td>341.9 206.1</td>
<td>1.38 0.66</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>0.13 0.11</td>
<td>4.6 3.3</td>
<td>329.4ab 226.7</td>
<td>1.03 0.65</td>
</tr>
<tr>
<td>Mean CT</td>
<td></td>
<td>0.13 0.14</td>
<td>5.2 4.3</td>
<td>315 238.3</td>
<td>1.22 0.55</td>
</tr>
<tr>
<td>Mean CF</td>
<td></td>
<td>0.13 0.12</td>
<td>4.9 4.4</td>
<td>318.9 221.9</td>
<td>1.34 0.58</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>*</td>
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<tr>
<td>PxF</td>
<td></td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns: not significant
* statistically significant at level 0.05
** statistically significant at level 0.01
2.2. Soil Nutritional Status during the 4 years of the Experiment

Figure 8 refers to the change in average soil total nitrogen content (%) during all over the experiment.

![Figure 8](image)

Over the four years of the experiment, soil nitrogen content seemed to show an increasing trend compared to its initial level. After zucchini (2008-2009 T0), the N concentration was at the lowest level; it then increased and stayed rather stable. Statistically, there were no significant differences among tested treatments at each individual sampling date.

According to the reference values cited in Loue (1968), total soil nitrogen content is identified as high (Table 7).

**Table 7: Classification of total soil nitrogen content in soil**

<table>
<thead>
<tr>
<th>Sufficiency group</th>
<th>Very low</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>&lt;0.070</td>
<td>0.071-0.090</td>
<td>0.091-0.110</td>
<td>0.111-0.130</td>
<td>&gt;0.130</td>
</tr>
</tbody>
</table>
Figure 9 refers the changes in average soil available phosphorus (ppm) content during all over the experiment.

![Image of Figure 9 showing changes in average soil available phosphorus content during the experiment.](image)

**Figure 9.** Changes in average soil available phosphorus content during the experiment. Means with different letters are significantly different (Duncan test; alpha=0.05)

Soil available phosphorus content showed fluctuations during the experiment. The lowest values were obtained after zucchini in 2008 and after the pre-crops in 2010. The highest level was obtained after pepper (2009-2010 T0). However, after incorporation of the pre-crops in 2008-2009 cycles, even if there was no statistically significant differences between the treatments the highest available phosphorus content was after the vetch and the lowest after broccoli.

According to Hafez and Mahmoud (2009) phosphorus plays a great role to improve the plant growth of some Solanaceae family such as eggplant, tomato, potato and pepper.

Soil phosphorus level fluctuated over the four years. However according to the Jackson (1958) reference values for soil available phosphorus content revealed sufficiency (Table 8).

**Table 8: Classification of soil available phosphorus (ppm) content in soil**

<table>
<thead>
<tr>
<th>Sufficiency group</th>
<th>Poor</th>
<th>Moderate</th>
<th>Sufficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>P (ppm)</td>
<td>&lt;1.30</td>
<td>1.30-3.26</td>
<td>&gt;3.26</td>
</tr>
</tbody>
</table>
Figure 10 illustrates the change in average soil available potassium (ppm) content during all over the experiment.

![Graph showing changes in soil available potassium content](chart.png)

Figure 10. Changes in average soil available potassium content
Means with different letters are significantly different (Duncan test; alpha=0.05)

Potassium levels in soil decreased over the four years of the experiment. Strong reduction was especially found after pepper (2009-2010, T0) probably because pepper is one of the highest potassium demanding vegetables (105-175 kg/ha) compared to other vegetable species (Terbe et al., date not known).

The overall effects of pre-crops were found significant (Figure 11), faba bean and fallow were grouped together. Broccoli was the least contributor to soil K among tested treatments; vetch was statistically indifferent with both groups.

![Graph showing effect of pre-crops on soil available potassium content](chart2.png)

Figure 11: Effect of pre-crops on soil available potassium content Means with different letters are significantly different (Duncan test; alpha=0.05)

The levels obtained in the experiment display a range between high to very high soil available potassium (Table 9).
Table 9. Classification of soil available potassium (ppm) content in soil (Prizer, 1967)

<table>
<thead>
<tr>
<th>Sufficiency group</th>
<th>Very low</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>K (ppm)</td>
<td>&lt;100</td>
<td>100-200</td>
<td>200-250</td>
<td>250-320</td>
<td>&gt;320</td>
</tr>
</tbody>
</table>

Average soil organic matter contents fluctuated all over the experiment. The levels were lower after the pre-crop but higher after the main crop (Figure 12). However, there was no statistically significant effect of fertilization treatment at each sampling date.

Figure 12. Changes in average soil organic matter (%) content during Means with different letters are significantly different (Duncan test; alpha=0.05)

The four year evaluation of pre-crops shows that the overall effect of tested pre-crops on soil organic matter was significantly different. Vetch increased soil organic matter the most, followed by faba bean and fallow. Broccoli was listed as the lowest (Figure 13). Vetch can reduce erosion; add N and organic matter to the system (Clark A., 2006).

Figure 13: Effect of pre-crops on soil organic matter content Means with different letters are significantly different (Duncan test; alpha=0.05)
However, according to the reference values cited in Thun et al. (1955), soil organic matter content is identified as moderate in all subplots (Table 10).

### Table 10: Classification of soil organic matter content in soil

<table>
<thead>
<tr>
<th>Sufficiency group</th>
<th>Very low</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>O.M. (%)</td>
<td>&lt;1</td>
<td>1-2</td>
<td>2.3</td>
<td>3-6</td>
<td>&gt;6</td>
</tr>
</tbody>
</table>

### 3. Pre-crops

#### 3.1. Yield

During 2009-2010 pre-crop cycles, broccoli heads could not be harvested in all treatments. Heavy rain, limitations in light and low temperature regimes during broccoli life cycle are assumed to cause this result. The temperatures ranged below the optimum, 25 °C, (Smith and Doubrava, 2003). Similar situation was observed in many farms throughout the Aegean Region in Turkey where the experimental site is located.

The total faba bean yield harvested in both CF and CT subplots were similar in terms of weight. Faba bean pods were harvested at two different times. Total faba bean yield in compost tea subplots reached 8165 (kg.ha\(^{-1}\)) and in commercial fertilizer subplots it reached 8577.5 (kg.ha\(^{-1}\)). There was no significant difference between the treatments. The size of faba bean was almost similar in subplots that received compost tea or commercial fertilizer. Statistically, there was no significant effect of the tested pre-crops or fertilization strategies.
3.2. Biomass Production

The following figure shows the biomass production produced by the pre-crop and spontaneous vegetation in different treatments during the pre-crop growth cycle.

![Biomass Production Graph]

*Values show the actual amount of biomass based on its share of each bar*

Natural vegetation in fallow subplots fertilized with compost tea treated was 23581 kg and commercial fertilizer treated plot had 17047 kg.ha\(^{-1}\) (Figure 14).

The faba bean biomass produced per hectare in commercial fertilizer (345886 kg) applied subplots exceeded those of compost tea plots (340510 kg). On the other hand, biomass of natural vegetation in compost tea was higher than in commercial fertilizer plots.

In vetch plots, biomass produced per hectare in commercial fertilizer (30326 kg) exceeded those of compost tea subplots (27856 kg) plots. On the other hand, natural vegetation was higher in compost tea yielding to almost equal total biomass production on fresh basis.

In broccoli plots, the fresh biomass accumulated by the natural vegetation was more than the broccoli in both subplots. Spontaneous vegetation biomass was 26030 kg and 17018 kg per hectare in CT and CF subplots. The growth of natural vegetation was higher than the broccoli, farmer’s choice since vegetative growth of broccoli was suppressed and retarded due to adverse climatic conditions. Natural vegetation captured the sun and water from the heavy rainfall and grew better than broccoli.

In all the plots, spontaneous vegetation produced more biomass in compost tea fertilization than the commercial fertilizer applied sub-plots. For the pre-
crops (faba bean, vetch and broccoli), the situation was opposite: all the pre-
crops produced more biomass in commercial fertilizer applied sub-plots
compared to compost tea fertilized ones. Spontaneous vegetation’s biomass
was lightest for vetch plots possibly due to vigorous growth of vetch and
coverage of soil surface. On the other hand, broccoli plots have the highest
spontaneous vegetation because of the low biomass of broccoli plants.
Statistical analysis showed significant effects of pre-crops and fertilization on
fresh and dry biomass of spontaneous vegetation (Table 11). The biomass
levels obtained from different pre-crop subplots were different. The highest
fresh biomass was obtained in faba bean plot followed by natural vegetation
in fallow subplots. Almost similar results were obtained for dry biomass. The
effects of pre-crops were more related to cultural practices done to subplots
than the effect of the pre-crop itself.

Table 11: Statistical analysis of fresh and dry biomass produced by
spontaneous vegetation

<table>
<thead>
<tr>
<th>Pre Crops (P)</th>
<th>Fertilization Program (F)</th>
<th>Fresh Biomass (kg.ha$^{-1}$)</th>
<th>Dry Biomass (kg.ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallow</td>
<td>CT</td>
<td>23581</td>
<td>12014</td>
</tr>
<tr>
<td></td>
<td>CF</td>
<td>17047</td>
<td>8066</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>20314 ab</td>
<td>10040 ab</td>
</tr>
<tr>
<td>F.Bean</td>
<td>CT</td>
<td>22752</td>
<td>10893</td>
</tr>
<tr>
<td></td>
<td>CF</td>
<td>21204</td>
<td>9554</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>21978 a</td>
<td>10224 ab</td>
</tr>
<tr>
<td>Vetch</td>
<td>CT</td>
<td>13198</td>
<td>6172</td>
</tr>
<tr>
<td></td>
<td>CF</td>
<td>14065</td>
<td>5506</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>13631 b</td>
<td>5839 b</td>
</tr>
<tr>
<td>Broccoli</td>
<td>CT</td>
<td>26030</td>
<td>12381</td>
</tr>
<tr>
<td></td>
<td>CF</td>
<td>27018</td>
<td>18622</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>26524 a</td>
<td>15501 a</td>
</tr>
<tr>
<td>Mean CT</td>
<td></td>
<td>21390 a</td>
<td>10365 b</td>
</tr>
<tr>
<td>Mean CF</td>
<td></td>
<td>17333 b</td>
<td>7937 b</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>*</td>
<td>*</td>
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<td>P</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>PxF</td>
<td></td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns: not significant
* statistically significant at 0.05 level
** statistically significant at 0.01 level
4. Main Crop Growth Cycle

4.1. Eggplant Biomass Production

The following figure shows the biomass production by the main crop.

Among tested treatments only pre-crops had marked effect on biomass of eggplant plants. Plots where faba bean was the pre-crop had the highest biomass and broccoli the lowest. Fallow and vetch were ranked in between and placed in the same statistical group (Figure 15). Despite the significant effect of pre-crops, it was not reflected on yield since besides vegetative growth, some other factors such as number of flowers, rate of pollination, fruit set and fruit development also affect yield.
4.2. Yield

Pre-crops did not have any significant effect on eggplant yield. However fertilization programme affected eggplant yield significantly (Figure 16).

![Figure 16. Effect of tested fertilization strategies on eggplant yield (bars with different letters show significant differences for p < 0.01)](image-url)

Plots treated with commercial fertilizer resulted in higher yields. Eggplant plots treated with compost tea had significantly lower yield and number of fruits. Similar effect was obtained with vetch during the pre-crop cycle. Even though there was no statistically significant effect of the tested pre-crops, the highest yield was obtained in plots of vetch followed by faba bean, fallow and broccoli in the decreasing order. According to the reference values of Bilen (2008), plots following vetch gave the highest yield group during zucchini production. Number of the fruits showed a similar trend as the total yield.

Thomopoulos (2008) tested vetch (Vicia sativa) and faba bean (Vicia faba) as green manures in organic cotton production in clay loam soil (Athens, Greece) in 2005 and 2006 and no significant effect of green manuring on yield was obtained.

Humic acid (HA) is the result of organic matter decomposition and is beneficial to plant growth and development. Karakurt et al., (2009) found that the soil HA application affected on fruit quality and yield of organically grown pepper which is from same family with eggplant. According to our results, commercial fertilizer which has high humic acid content augmented eggplant yield.
Figure 17 illustrates the cumulative yield of eggplant.

Eggplant harvest started on July 19, and yield measurement was terminated on August 16, 2008 even if fruit set and maturation continued partially (Figure 17).

Harvested fruits were screened for the defected fruit, and the total amount of fruits that have market quality was identified as ‘marketable yield’. Percentage of marketable fruit in the total yield was very high, almost equal to total amount of harvested eggplants in every treatment. Only few fruits were found as defected. The effects of tested variables, pre-crops and fertilizer treatment or their interaction were not significant on marketable yield or percentage.

4.3. Quality

The quality parameters such as length and diameter of the main crop are displayed in the following Figure 18 and 19.

Figure 17. Cumulative yield of eggplant (kg.ha\(^{-1}\))

Figure 18. Length of main (cm) crop fruits
Mean with different letters are significantly different (Duncan test; alpha=0.05)
Statistical analysis showed that fertilization treatments affected length of eggplant fruit significantly and commercial fertilizer increased length on the average by 1 cm (Figure 18). Compost tea treated plots yielded significantly shorter eggplant fruits compared to commercial fertilizer treated plots.

![Figure 19. Diameter (mm) of main crop fruits](image)

Means with different letters are significantly different (Duncan test; alpha=0.05)

As could be seen in Figure 19, pre-crops affected the diameter of eggplant. Broccoli, fallow and vetch gave the highest values for the diameter of eggplant. The lowest value was obtained in eggplant plots following faba bean. On the other hand, firmness, mean weight and dry matter content of eggplant fruit were not affected by the tested factors.

The average sizes were in conformity with the sizes stated in UN/ECE standard. Size is determined by the shoulder diameter (width) of the eggplant. In the case of eggplant the term "width" means the maximum equatorial diameter. The width of eggplant may not be less than 40 mm in order to take place in class A, the highest quality class. Results obtained from experiment showed that all tested treatments gave class A fruit.

For weight, according to UN/EC standard; the minimum weight is fixed at 100 g. Results showed that all treatments gave class A fruit. Eggplant must have a minimum length excluding peduncle of 80 mm in UN/ECE standard. Results obtained that mean of the length for all treatments higher than standards.

Statistical analyses showed that there were no significant differences between the treatments for the titratable acidity content. The Figures 20, 21 and 22 show some chemical quality attributes of eggplant fruits such as EC, pH and RDS content.
Fertilization treatments had significant (P< 0.05) effect on fruit pH and EC; however, the differences were not high. Commercial fertilization resulted in higher pH than compost tea. Compost tea revealed higher EC levels compared to commercial fertilizer treated plots (Figure 20 and 21).

The pre-crop treatments had significant (P<0.01) effect on RDS which ranged between 4.7 and 5.4. Vetch gave the highest value where as the lowest result was obtained in plots following fallow and faba bean (Figure 22). Higher dry matter and RDS contents affect shelf-life of eggplants. However despite the significant differences, longer term results are required to assess the effects of CT and CF on eggplant quality.
5. Weed Assessment

5.1. Spontaneous Vegetation during Pre-crop Growth Cycle

Table 12 shows that there were totally 162 to 294 plants and 4 to 7 species in each subplot. The highest number of spontaneous vegetation occurred in fallow followed by faba bean, broccoli and vetch in decreasing order. For species number, the highest diversity was seen in fallow and faba bean. Broccoli was almost same as faba bean. Vetch subplots have the lowest biodiversity of spontaneous vegetation due to vigorous growth and higher coverage. Broccoli and faba bean has higher spontaneous vegetation. The reason is probably as a consequence of suppressed growth of broccoli plants and slow growth of faba bean. The weak competition between broccoli and faba bean and spontaneous vegetation let the weeds grow more.

5.2. Spontaneous Vegetation during Main Crop Growth Cycle

There were a total of 58 to 107 plants and 3 to 5 species in each subplot (Table 13). The highest number of spontaneous vegetation was in eggplant following vetch as a pre-crop. It was followed by fallow, faba bean and broccoli subplots. Even if it was not significant, broccoli and faba bean plots had the lowest number of spontaneous vegetation during the main crop production cycle. For broccoli the effect can be explained by the allelopathic effect of broccoli and fast growth of faba bean plants during the later stages of precrop cycle. Bell and Muller (1973) also stated that members of Brassicaceae have frequently been cited as allelopathic crops, and volatile compounds like isoprenoid and benzenoid compounds released from Brassica tissue degradation may suppress weed growth (Tollsten and Bergstrom, 1988).

Figure 22. RDS (% Brix) of main crop fruits
Means with different letters are significantly different (Duncan test; alpha=0.05)
Table 12: Biodiversity of spontaneous vegetation during pre crop growth cycle

<table>
<thead>
<tr>
<th></th>
<th>Fallow</th>
<th>Faba Bean</th>
<th>Vetch</th>
<th>Broccoli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilization</td>
<td>CT</td>
<td>CF</td>
<td>CT</td>
<td>CF</td>
</tr>
<tr>
<td>No. Of plants</td>
<td>242</td>
<td>294</td>
<td>281</td>
<td>209</td>
</tr>
<tr>
<td>No. Of Species</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Species name</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stellaria media</td>
<td>49,44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alopecurus myosuroides</td>
<td>37,84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convolvulus arvensis</td>
<td>2,52</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Senecio spp.</td>
<td>0,98</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calendula officinalis</td>
<td>0,55</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 13: Biodiversity of spontaneous vegetation during main crop growth cycle

<table>
<thead>
<tr>
<th>Fertilization</th>
<th>Fallow</th>
<th>Faba Bean</th>
<th>Vetch</th>
<th>Broccoli</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CT</td>
<td>CF</td>
<td>CT</td>
<td>CF</td>
</tr>
<tr>
<td>No. Of plants</td>
<td>76</td>
<td>60</td>
<td>65</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species name</th>
<th>%</th>
<th>Species name</th>
<th>%</th>
<th>Species name</th>
<th>%</th>
<th>Species name</th>
<th>%</th>
<th>Species name</th>
<th>%</th>
<th>Species name</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convolvulus arvensis</td>
<td>35.1</td>
<td>Portulaca oleracea</td>
<td>42.7</td>
<td>Portulaca oleracea</td>
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<td>41.8</td>
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<td>40.2</td>
<td>Convolvulus arvensis</td>
<td>37.8</td>
</tr>
<tr>
<td>Sorghum halepense</td>
<td>30.7</td>
<td>Cyperus rotundus</td>
<td>32.1</td>
<td>Sorghum halepense</td>
<td>40</td>
<td>Sorghum halepense</td>
<td>18.6</td>
<td>Portulaca oleracea</td>
<td>23.8</td>
<td>Portulaca oleracea</td>
<td>22.1</td>
</tr>
<tr>
<td>Cyperus rotundus</td>
<td>21.6</td>
<td>Convolvulus arvensis</td>
<td>25.2</td>
<td>Convolvulus arvensis</td>
<td>10</td>
<td>Portulaca oleracea</td>
<td>17.5</td>
<td>Portulaca oleracea</td>
<td>17.9</td>
<td>Sorghum halepense</td>
<td>15.1</td>
</tr>
<tr>
<td>Portulaca oleracea</td>
<td>12.6</td>
<td>Cyperus rotundus</td>
<td>10</td>
<td>Cyperus rotundus</td>
<td>12.7</td>
<td>Medicago spp</td>
<td>10.1</td>
<td>Cyperus rotundus</td>
<td>14.1</td>
<td>Cyperus rotundus</td>
<td>9.2</td>
</tr>
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</tr>
</tbody>
</table>

**Main Species**

- **Convolvulus arvensis**
- **Portulaca oleracea**
- **Sorghum halepense**
- **Cyperus rotundus**
- **Medicago spp**
6. Economic Analysis

The total gross margin, of both the pre-crop and the main crop, of sub plots fertilized with commercial fertilizer was higher than the one registered in the subplots where compost tea fertilization was used, and this applies to all treatments independently from the rotation done. The high values of the total GM in all the plots fertilized with CF is mainly related to the high production (yield) obtained with these treatments in comparison to the compost tea ones.

Regarding the total revenues of the different rotations, faba bean-eggplant fertilized with CF showed the highest value (383,83 €/100m²) as a result of the faba bean revenue contribution (82,67 €/100m²) and to the total variable costs that were not very high. However, the main crop highest revenue was registered in the sub-plots with vetch-eggplant rotation fertilized with CF (318,58 €/100m²) due to the highest main crop yield obtained from these sub-plots.

The lowest value of the total revenue was registered in broccoli sub plots due to the failed harvest of broccoli (no yield was picked) due to climatic conditions such as heavy rain, limitations in light and low temperatures, add to that the low yield of eggplants after the broccoli.

The highest total variable costs were registered in the broccoli-eggplant rotation. This is primarily due to the high broccoli’s seedlings costs. In this case the lowest total gross margin was obtained in these treatments in comparison to the others.

Table 14 shows the revenues variable costs and gross margin of the production cycle.
Table 14: Economic analysis of the eight different treatments (€/100m²)

<table>
<thead>
<tr>
<th></th>
<th>Broccoli</th>
<th>Vetch</th>
<th>Faba Bean</th>
<th>Fallow</th>
</tr>
</thead>
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Chapter 4: Conclusions and Recommendations

The effect of pre-crops was not significant on eggplant yield but vetch as pre-crop gave the highest yield compared to the others. For this reason agronomically, vetch-eggplant crop rotation can be suggested as the best crop rotation under experimental conditions. On the other hand, pre-crops had significant effect on diameter and RDS of eggplant. The variables tested in the pre-crop cycle, fallow, vetch, faba bean or broccoli had no effect on some physical quality parameters as firmness, dry matter and mean weight and chemical quality as titratable acidity of eggplants.

Fertilization strategy as commercial fertilizer gave higher yield compared to compost tea. Therefore commercial fertilizer can be recommended the best fertilization strategy under experimental conditions. Fertilizers affected the length, ph and EC of eggplant fruit significant at statistical level.

Under the climatic conditions of the experimental field, faba bean can be recommended mainly for incorporation at blossom period if grown as N-fixing legume also vetch can be used to increase the soil fertility in terms of phosphorus and organic matter. Results showed that broccoli production may be unsuccessful and create problems due to adverse climatic conditions even if rarely.

During the pre-crops growth cycle, vetch can be recommended to suppress the spontaneous vegetation due to vigorous growth and higher coverage. On the other hand broccoli cannot be suggested due to adverse climatic conditions.

Economically faba bean – eggplant crop rotation treated with commercial fertilizer can be recommended that the most profitable rotation programme as regard of gross margin under the experimental conditions.

Agronomically, during all over the experiment the most recommended rotation was vetch as pre-cop and commercial fertilizer as fertilization strategy but economically the best suggested rotation was faba bean as pre crop and compost tea as fertilization strategy under experimental conditions.

Based upon the obtained results and experiences gained, the following recommendations could be made for the coming year:

Soil available potassium and available phosphorus levels have to be considered for the experimental field because especially phosphorus constantly decreased in the soil.
A main crop with a shorter lifecycle may allow more time for the final evaluation of the experiment as a Masters’ thesis.

The calendar needs to be revisited, and the sowing or transplanting dates must be taken to an earlier date in order to allow adequate time span for harvesting pre-crops and to have adequate time between incorporation of soil building crops and the transplantation of the main crop.

There should be leguminous plots which do not receive fertilization to make further comparisons.

Pruning may be applied to eggplants to extend the harvest period and increase the yield.

For the coming years or in similar experiments, pre-crops and main crops which have deeper roots may be tested.

Finally, for the second phase of the experiment to be carried out as on-farm trial, eggplant following vetch as the commercial legume with Pow humus as commercial fertilizer can be a good alternative due to high profit and low pest and disease incidence risk.
REFERENCES


Draper M., Burrows R., Munk S. (2002). Blossom end rot of tomatoes and other vegetables. Plant Disease Management In South Dakota.

Duman İ., Kaya S. (2010). Organic Vegetable Growing, Ege University, Faculty of Agriculture, Horticulture Department, Turkey.


