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Effect of vetch wheat mixture and broccoli as preceding crops on organic summer vegetables: on farm trial in western Turkey

Abstract

Organic farming requires the use of practices such as crop rotation, green manure and compost application instead of chemical compounds to enhance farm productivity. In this study, effects of two pre-crops (vetch-wheat mixture and broccoli) and additional fertilization (AF) strategy (compost and commercial fertilizer) were tested on organic production of two main crops (tomato and zucchini) and on soil fertility. The main aim of this on-farm trial is to evaluate the applicability of the results obtained over four years study under experimental conditions. Pre-crops and AF strategy had no significant effect on zucchini yield; highest tomato yield was recorded after vetch-wheat mixture and AF. At the end of the cycle soil organic matter statistically increased in vetch-wheat mixture with AF plots. Soil nitrogen (N) levels increased slightly in all treatments but this increase was not significantly different from the initial level of N. Vetch-wheat mixture and tomato rotation with AF provided the highest gross-margin due to a higher yield.

Key words: Organic agriculture, soil fertility, crop rotation, organic fertilizers, pre-crop, tomato, zucchini.

Dedication

This modest work is dedicated to the one who stands by me with her love and support in every moment of glory and misery in last seven years of my life.

My fiancée Duygu ALTIN

And to the most preeminent educationalist that I have ever had during my education life.

Prof. Dr. Uygun AKSOY

Beyond all, to the most precious being of my life with their unrequited love and support.

My Family

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List of Abbreviations

T1: First treatment or plot with broccoli as pre-crop treatment, and main crops fertilized.

T2: Second treatment or plot with vetch and wheat mixture as the pre-crop treatment and main crops were fertilized.

T3: Third treatment or plot with vetch and wheat mixture as the pre-crop treatment, and no additional fertilization during main crop cycle.

AF: Additional fertilization applied as compost and commercial fertilizer

Ns: Not significant

t0: Soil sampling date before pre-crops

t1: Soil sampling date 3 weeks after pre-crops

t2: Soil sampling date after main-crops.

OM: Organic Matter

N: Nitrogen

P: Phosphorus

K: Potassium

Ca: Calcium

Mg: Magnesium

Gm: Gross margin

Dm: Dry matter

WDSM: Water-soluble dry matter

g: Gram

cm: Centimeter

Introduction

The popularity of using organic farming techniques to grow crops has increased in recent years as a consequence of both enhancing consumer demand for organically grown products and farmers willingness to sustain or improve soil fertility (Rosen and Allan, 2002).

Crop rotation is one of the key practices in organic farming that can improve farms fertility. It affects the economic and environmental performance of cropping systems and is important for the design and realization of sustainable agricultural systems (Schönhart *et al.,* 2009).

Organic farmers use crop rotations, cover crops and compost to maintain or enhance soil fertility. By using crop rotations they improve the farms diversity and increase the populations of beneficial insects. Improved diversity provides pest and disease suppression (Delate, 2003).

High usage of chemical fertilizers and their negative effects has raised interest for using organic amendments for soil nutrient improvement. Synthetic fertilizers can be substituted by the organic amendments, such as compost, for greater stability and sustainability of the crop production (Roy *et al*., 2010).

This study is carried out under farm conditions as the second phase of a common research project - coordinated by the Mediterranean Agronomic Institute of Bari in the framework of its Mediterranean Organic Agriculture' Master program – that was adopted by four institutes in the Mediterranean countries, Turkey, Italy, Tunisia and Morocco.

Objectives

The general objective of this work is to test the best precrop-fertilization strategy obtained between 2006-2010 at experimental level and to analyze the technical and economic feasibility of pre-crops in open field organic tomato and zucchini production with additional fertilization (compost and commercial fertilizer) under farm conditions in Manisa/Turkey.

The specific objectives are enumerated as follows:

- to determine the effect of the recommended treatments (soil building pre-crops and fertilization strategy) on organic tomato and zucchini plant growth, yield and fruit quality;
- to determine the effect of the treatments on soil fertility;
- to analyze the effect of vetch-wheat mixture alone;
- to conduct an economic analysis of organic tomato and zucchini production under farm conditions after two pre-crops.

Chapter 1: Literature Review

1. Soil fertility

Soil fertility is an important parameter to evaluate the productivity of a farm. Soil fertility is frequently defined as ‘’ability of a soil to provide adequate nutrients for cultivated crop on farm’’ however it is more suitable to define soil fertility as an ecosystem concept integrating the diverse soil functions, including nutrient supply, which promote plant production (Watson *et al*., 2002).

There are many ways to provide sufficient nutrients for plants both in conventional and organic farming systems however in conventional farming systems, a farmer mainly focus on short term solutions and nutrients that are essential for an optimal yield through synthetic fertilizers. These applications have a negative impact on environment such as nutrient leaching to the ground water due to excessive use and high solubility, and energy consumption to produce and transport synthetic fertilizers (Mader *et al*., 2002).

On the other hand, in organic systems, a farmer mainly relies on long term solutions and management of soil organic matter to improve the chemical, biological and physical properties of the soil, in order to provide sufficient nutrients for an optimal crop production (Watson *et al*., 2002).

For a fertile soil, farmers need to optimize the following soil properties;

- *Physical properties*
  Bulk density, rooting depth, water infiltration rate, water-holding capacity, and aggregate stability.
- *Chemical properties*
  pH, electrical conductivity, cation-exchange capacity, organic matter, mineralizable nitrogen, exchangeable potassium and calcium.
- *Biological properties*
  Microbial biomass carbon, microbial biomass nitrogen, earthworm enzymes, and disease suppression capacity.

Since soil organic matter (SOM) influences many soil properties such as infiltration rate, bulk density, cation exchange capacity, biological activity and some others, improving the SOM is a relatively easier way to optimize the mentioned properties. Additionally, SOM serves as a slow release reservoir that provides macro nutrients, especially nitrogen, and also micro nutrients for plant. Evanylo *et al*. (2008) report that soil physical properties are improved by using compost as a fertilizer, and the high annual application of the compost increases the soil C, N and P concentrations more than the standard fertilization.

2. Crop Rotation

Crop rotation is designing successive crops that will bring high benefits due to their sequence, and it has two aspects that are spatial and temporal. Spatial aspect is the crops grown in one year and their division over the available space, whereas temporal aspect is when crops are grown over time in a specific order (Wijnand, 1999).

Crop rotation is very essential and contains many aspects that are necessary for organic farming systems. Crop rotation affects the final farm outputs as a whole as well as the inputs of nutrients for the maintenance of soil fertility. Crop rotation and the associated management also determine the impacts on environment, e.g. through nitrate leaching (Olesen *et al*., 1999).

European regulation obliges crop rotation in (EC) 834/2007 as ‘’ the fertility and biological activity of the soil shall be maintained and increased by multiannual crop rotation including legumes and other green manure crops…’’. Besides farmers have to keep their rotation plans in the farm records to show them as an evidence to the inspector who is commissioned by the inspection body.

Organic agriculture approves that crop rotation is a crucial practice to sustain farms productivity. Expert farmers plan their rotations to ‘’earn income’’ and ‘’increase soil quality or build soil capital’’ (Farmers also use this term to express how the practices, that improve soil fertility, are an investment for long term soil productivity). In addition to this, there are some common goals for the farmers, as increase of profitability by keeping inputs as low as possible, maintain healthy soil, control pest and diseases, reduce weed pressure etc… To achieve these goals, it is inevitable for a farmer to apply a crop rotation plan in his/her farm (Johnson and Toensmeier, 2009).

2.1. Legumes as Green Manure

Green manure is a plant that is used as a soil amendment and a nutrient resource for the following crops (Cherr *et al*., 2006) and farmers use legumes as green manure to improve their soils’ physical, chemical and biological properties (Özpınar and Baytekin, 2006).

There are a lot of major problems in agriculture; one of them being the breakdown of soil humus and its quality that is caused by the reduction in soil organic carbon and total nitrogen (Maiksteniene and Arlauskiene, 2004). For

organic farmers, biological N fixation is a very important tool to supply N (Balnyte *et al.,* 2009) and legumes can fix atmospheric N by incorporation with the soil Rhizobium bacteria. Using legumes in a crop rotation can provide free nitrogen and as a consequence it can decrease the amount of fertilizers required to supply N. On the other hand, using legumes can reduce pest and weed occurrence (Kessel and Hartley, 2000).
When a farmer uses legumes as green manure, he/she and the environment will have multiple benefits from this application. Green manure compared with the synthetic fertilizers, is a renewable on-farm resource without any transportation costs, or consumption of fossil fuels. In addition to this, slow release of the N from the residues can improve the N- uptake efficiency, reduce the leaching loss and thus, prevent pollution of ground water. Another advantage of biological N fixation is that it may also fix and add large amounts of C to the cropping systems (Cherr *et al.*, 2006).

2.2. Residue Management

In the last few decades, interest on the management of crop residues increased due to the disadvantages of the present techniques for instance burning and removing the residues. Since these techniques causes direct loss of nutrients and deprivation of the carbon and organic matter which is important for the soil structure and biota. According to the economic concerns and sustainability issues, retaining crop residues in the field is a better option for the farmers (Kumar *et al*., 2002).

Crop roots and residues improve soil fertility by motivating soil microbial communities and improving soil aggregation, these advantages lead to increased water infiltration, water holding capacity, aeration, and consequently root growth and nutrient foraging (Rangarajan, 2009). Field residues from broccoli harvest may provide nearly 7.5 tons.ha^{-1} dry matter to the soil (Mitchell *et al., 2000*)

Crop residues can release large amounts of mineral nitrogen in particular vegetable residues, which are rich in N such as Brassicas. However when the residues are incorporated in the autumn it can promote N losses by leaching before or at the start of the winter period (Neve *et al*., 1998).

Trinsoutrot *et al*. (2000) found that the crop residues can provide fresh organic matter input and incorporation of rape (*Brassica napus)* residues in soil leads to rapid decomposition of the C- substrate added and large N immobilization of N in soil. Castellanos *et al.* (2001) stated that incorporating broccoli residues to the soil increases the nitrogen use efficiency and found that maize can recover 42% of 100 kg N ha^{-1}, which is applied during the growth of broccoli, from the harvest residues.

3. Compost

Extensive use of chemical fertilizers and their adverse effects has increased the interest of using organic amendments for soil nutrient improvement. Chemical fertilizers can be substituted by the organic amendments for greater stability and sustainability of the crop production (Roy *et al.*, 2010).
One of these organic amendments is the compost application; it has been performed for many centuries to provide organic matter and nutrients to the soil. Nutrient and water holding capacity, aggregate stability and a well balanced microbial community are strongly related to the content of soil organic matter, and compost application contributes to the improvement of soil organic matter (Smidt *et al.*, 2008).

Tejada *et al*. (2009) concluded that the use of composted plant residues has a positive effect on the soil chemical, physical and biological properties. The C/N ratio of the composted organic materials strongly influence the soil biological activity and consequently the mineralization and soil restoration.

Wells *et al*., (2000) stated that the compost application provides sufficient nutrition for the vegetable production without damaging the soil health. It improves the soil health because large inputs of compost results in higher soil organic carbon, microbial biomass, total nitrogen, total phosphorus, exchangeable nutrient cations, water holding capacity and aggregate stability.

In a comparison with the application of the compost with and without cover crop and mineral fertilizer application, treatments with compost (20 $Mg.ha^{-1}$) and compost (10 $Mg.ha^{-1}$) + Cover crop (hairy vetch) provided nearly the same tomato yield. In addition to this, both treatments provided significantly higher tomato yield than the mineral fertilizer treatment (168kg NH_4NO_3. ha^{-1}) (Carrera *et al*., 2007). Another experiment showed that the replacement of mineral fertilizers with compost appears to be a good solution for tomato crops in both open field and green house production (Blanco *et al*., 2011).

4. Used species

4.1. Precrops

4.1.1. Common vetch (Vicia sativa spp.) mixed with wheat (Triticum aestivum)

Common vetch is one of the most important annual forage legumes in the Mediterranean, according to its multiple uses such as hay, grain, straw and green manure. Also it has a high nutritional value and ability to grow over wide range of climatic and soil conditions (Fırıncıoğlu *et al.,* 2010).

Common vetch has a scrambling and climbing growing habit and a tap root system with several lateral branches. It shows a better growth in humid and cool climatic conditions and prefers well-drained moderately fertile soils with a 6.0-7.0-pH value. In temperate regions between October and April rainfall of 200-400 mm is sufficient for its cultivation (Frame, [*n.d.*])

Monoculture production of the common vetch does not provide sufficient biomass for forage and green manure due to its superficial growth. Traditionally, particularly in Mediterranean region, mixtures of winter cereals and common vetch are used extensively for forage production, because cereals provides structural support for common vetch growth and this results in improved light interception consequently a better biomass (Lithourgidis *et al*., 2006).

4.1.2. Broccoli (Brassica oleracea L. var. italica)

Broccoli is a member of *Brassicaceae* family, it is morphologically similar to cauliflower. Edible parts consist of flower stalk and thick flower stems It forms a short erect stem that ends with a large green head of succulent flowers (Decoteau, 2000).

Broccoli commonly considered as a winter vegetable, is grown between autumn and spring, because high temperatures reduce the quality of marketable heads (Günay, 2004). It is not a selective plant in terms of soil requirements however it does not prefer nutrient-poor soils, particularly soils with high organic matter are suitable for broccoli production (Vural *et al*., 2000).

Harvest residues of broccoli provide nearly 7.5 tons.ha^{-1} dry matter to the soil (Mitchell *et al., 2000*), incorporating this residues can be a good solution for a reduction in fertilizer usage for the preceding crops.

4.2. Main Crops

4.2.1. Tomato (Lycopersicon esculentum)

Tomatoes are an integral part of human diet world wide. It is a member of the *Solanaceae* family and is a watery fruit containing 5-7 % dry matter. Although it contains relatively low concentrations of vitamin C, pro-vitamin A and minerals, compared to other fruit species it is major source of these nutrients because it is consumed in large quantities (McGlasson, 2003). The yield of tomato is variable according to the growing conditions, crop duration and the variety; it is between 60 – 120 ton ha^{-1} (Vural *et al*., 2000).

The optimum temperature for tomato production is between 20-27 °C. High and low temperatures cause a reduction in fruit setting. Tomato is not selective in terms of soil requirements, and it can be grown in every type of soil however in light soils production will be earlier than the heavy soils (Hanson, 2001).

In the Aegean and Mediterranean region of Turkey, farmers start to transplant tomato seedlings between April and May as spring production. In organic farms a careful crop rotation should be planned for increased yield and quality. Pea, faba bean, vetch, broccoli and cabbage are suggested as pre-crops in addition to this every 3-4 years vetch – cereal mixture can be used as green manure (Duman *et al*., 2010).

In open field conditions, requirement of nutrient peaks during fruit setting and according to the ash analyses of tomato crops it removes 110 $kg.ha^{-1}$ N, 25 $kg.ha^{-1}$ P and 150 $kg.ha^{-1}$ K from the soil when the yield is 40 $t.ha^{-1}$ (Günay, 2004).

Fungal and bacterial leaf spots and blights are common during warm, wet weather. Two common virus diseases of tomatoes are tomato spotted wilt virus (TSWV), which is transmitted by thrips, and tobacco mosaic virus (TMV), which is trans- mitted by contaminated tools and by people's hands or footwear (Ebesu *et al*., 2004).

The tomato red spider mite, *Tetranychus evansi* Baker & Pritchard, is an important pest of solanaceous plants, especially tomatoes. It feeds on plant cells and causes characteristic small, yellowish, speckled feeding marks. These marks are usually the first sign and are often confused with some fertilizer deficiencies. Fine, silken webs can be detected on heavily infested leaves and flowers with these plant parts quickly withering and turning brown (Soto *et al*., 2010).

Tuta absoluta is becoming a serious problem for tomato production in the Mediterranean region and causes severe damage on tomato fields. Its larvae mine the leaves and produce large galleries and burrow in to the fruit and thus lead to a massive reduction on the yield (Anonymous, 2009).

4.2.2. Zucchini (Cucurbita pepo L.)

Zucchini is a member of *Cucurbitacea* family and its cultivation is very widespread in Turkey. Zucchini plays an important role in human diet, since 100 g of zucchini fruit contains 1.4 g protein, 3.9 g carbohydrate, 0.2 g fat, 22 cal energy (Paksoy *et al*., 2004). In the open field conditions, the yield varies according to cultivar, however, approximately 5 – 10 fruits can be harvested from one plant (Saygili, 2005).

Summer squash is a warm-season and short duration crop. Cool temperature slows the production however better yield and quality can be obtained as a result of lower virus pressure. The optimal germinating temperature range is 21° to 35°C and the optimal growing temperature range is 18° to 24°C (Molinar *et al*., 1999).

Zucchini grows best on fertile, well-drained soil supplied with organic matter. The ideal pH for zucchini growth is between 6.0 and 7.5, but it will grow on soils with a pH of up to 8.0 (Vural *et al*., 2000).
In the Aegean region, zucchini production can be started during the spring or at the end of summer for two different market periods. For organic zucchini production, a crop rotation plan should be applied. Legumes, onion, brassicas are good pre-crops for zucchini (Duman *et al*., 2010).

Viruses are the most limiting factor in zucchini production, particularly during summer and fall months. Fruit distortion can be seen across squash types. The use of resistant verities is the only reliable control for diseases caused by viruses (Roberts and Kucharek, 2007).

Downy mildew is one of the most important leaf diseases in cucurbits. Typically, symptoms begin as small yellow areas on the upper leaf surface. As lesions expand, they may become brown with irregular margins. Affected areas may grow together, and the entire leaf may wither and die. The fruit is not affected but it will be less sweet (Boyhan *et al.*, 1999).

Aphids cause direct plant damage. The saliva injected during feeding can cause the foliage to become twisted, curled, or cupped downward. In addition to this, the excretion of excess sugar as honeydew can accumulate and support the growth of sooty mold on the upper surfaces of leaves. (Capinera, 2000).

Chapter 2: Material and Methods

1. Experimental Site

1.1. Farm Location and History

The trial is established in Koldere, a village of Manisa Province in western Turkey, at Şenaylar Farm. Ecocert certifies the experimental area for the last 4 years. Cereals were cultivated until 2008 and zucchini and cucumber were produced in 2009-2010 at the trial location.

Figure 1. General view of the experimental site.

1.2. Climatic Conditions

The region is characterized by a Mediterranean climate with dry summers followed by mild and rainy winters. In Manisa, precipitation is distributed as 24% in spring, 5% in summer, 24% in autumn and 48% in winter. The average rainfall is reported by the Turkish State Meteorological Service as 708.4 mm for the average of the last 40 years, and the annual rainfall is

406.2 mm in 2008, 969.6 mm in 2009 and 1075.2 mm in 2010.

1.3. Soil Properties

According to the analyses of soil samples taken at t0 (03.09.2010), the soil texture is sandy-clay-loam, pH is slightly alkaline (7.47), total salinity is 0.06 %, lime content 6.91%, organic matter content 1.28% and total N, available P and K content is 0.11%, 4.67 ppm, 617.57 ppm, respectively. Calcium and magnesium content is high, sodium is medium, iron and zinc is poor, copper and manganese is adequate.

1.4. Experimental Design

The experimental design is a split-split plot with 2 factors and 3 replications. The main factor is the pre-crops that are broccoli (T1) with compost and commercial fertilization during the main crop and vetch-wheat mixture with (T2) and without (T3) additional fertilization during the main crop. The second factor is the main crops that are zucchini and tomato. Each sub-plot covers 96 m^2 and the distance between the subplots is 1m to create a buffer zone (Fig. 2).

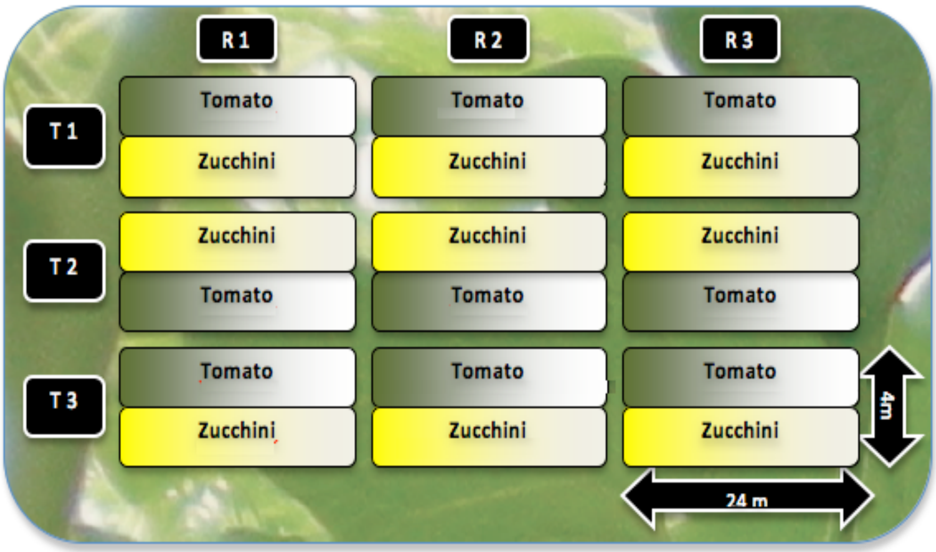


Figure 2. Experimental Design

1.5. Cultural Practices

All the soil-related cultural practices were kept at minimal level not to disturb the soil fauna. First, the soil was ploughed with mould-board plough and then harrowed with disk harrow to prepare the field on September 16th, 2010. On October 11th, 2011 chisel harrowing was performed to prepare the soil to sow vetch-wheat mixture. Before the main crops, pre-crops were incorporated and soil was ploughed and disk harrowed on May 09^{th}, 2011 to prepare the land for main crops, tomato and zucchini plants.

1.6. Irrigation

The experimental plots were irrigated by a drip irrigation system in order to have homogeneity in water distribution. During the pre-crop growth cycle broccoli plants were irrigated (41.9 m3) only in September 2010 due to the dry weather conditions, and vetch wheat mixture plots were not irrigated, as there was enough rain during their vegetation period. During tomato and zucchini crops was irrigated 335.9 m^3 and 440.8 m^3 respectively.

1.7. Plant Protection

Weed control was done by hoeing to minimize the competition with plants and adverse effect on soil fauna, and thus to minimize the carbon emission. Weeding was done once for the broccoli plots on September. For pest and disease control, preparations permitted in the EU and Turkish organic regulations (EC 889/2008 and TR 27677/2010) were used when necessary. During the pre-crop cycle, there was no application because of low pest incidence. For the main crops, Bordeaux mixture (400 g/100 l) was applied after transplantation against red mites. ‘’Laser’’ (Spinosad 480gr/l) was applied on 28^{th} June 2011 to tomato crop against bollworm.

2. Plant Material

2.1. Pre-crops

Two crops were tested as pre-crops: A mixture of Common vetch (*Vicia sativa*) and wheat (*Triticum aestivum*) at a ratio of 4:1 for incorporation and Broccoli (*Brassica oleracea* italica) as a commercial choice of the farmer with plant residues incorporated after harvesting heads.

Vetch and wheat seeds were untreated and unregistered, broccoli seeds of ‘Monopoly’ variety were purchased from Syngenta. Vetch-wheat mixture was sown manually as 100 kg.ha^{-1} vetch and 25 kg.ha^{-1} wheat seeds. Broccoli seedlings were transplanted manually as 48 000 seedlings.ha^{-1}.

2.2. Main Crops

Two crops were used as main crops, tomato (*Lycopersicon essculentum*) and zucchini (*Cucurbita pepo* L.). C33, a standard determinant tomato variety was used. Tomato seedlings, grown organically in the experimental field of Ege University, were transplanted manually on May 10, 2011 as 11 900 seedlings.ha^{-1}. Tomato fruit was harvested in August 2011.

Organically certified zucchini seeds of ‘Sakız’ variety provided by Asgen were sown manually directly to the field on May 10, 2011 as 3400 g seeds.ha^{-1}. Harvests were done between the end of June and end of August 2011.

3. Fertilization Program

Nutrition of main crops was maintained by applying a commercial compost (Bioaktif) and a commercial fertilizer (Pow humus) (Table 1). Bioaktif is produced by Çamlı Besi Company, İzmir, Turkey. Pow humus is produced by Humintech, Germany and is imported by IZOTAR Company, İzmir, Turkey and is permitted for use in organic agriculture according to Annex I of regulation (EC) 889/2008 and the Turkish regulation (TR 27677/2010) on organic agriculture.

Bioaktif compost was applied at a rate of 2000 kg.ha^{-1} to T1 and T2 plots prior to the transplantation of tomato seedlings and sowing of zucchini. Pow humus was applied to T1 and T2 plots for a total amount of 6.9 kg.ha^{-1} on three different dates (18th, 25th July and 1st August)

Table 1. Compositon of compost 'Bioaktif' and 'Pow humus'

	Bioaktif	Pow humus
Total Nitrogen	3.50 %	0.03 %
Organic Nitrogen	3.00 %	-
Total P_2O_5	3.00 %	-
Total soluble K_2O	3.00 %	12.00 %
Total organic matter	60.00 %	82.00 %
Humidity	20.00 %	14.00 %
pH	8	8-9
Total Potassium Humate	-	97.00 %
Humic acid	-	55.00 %
Fulvic acid	-	30.00 %

4. Sampling

4.1. Soil

Soil samples were collected before planting the pre-crops on September 03, 2010 (t0). The second samples (t1) were taken 3 weeks after the incorporation of the pre-crops on April 28, 2011 and the third sampling (t2) was done after the harvest of main crops. All the samples are collected with ‘’X’’ method, 5 pre-samples were collected for each plot and mixed to ensure the homogeneity in main sample. The samples were analyzed at Ege University, Faculty of Agriculture Soil Science and Plant Nutrition 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 and three tomato and zucchini plants were collected from each replication. A 25 x 25 quadrate was thrown randomly two times for the vetch-wheat mixture plots (T2, T3) and all the plants in the square were taken without breaking the integrity of the plants including roots.

4.3. Quality

Five broccoli heads were taken from each replication for quality analyses on December 09 and 14, 2010. Ten representative zucchini fruits were sampled on 5th, 13th and 29th of July 2011 from each replication. Ten tomato fruits were sampled on 1st and 8th of August 2011.

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).

Available N was determined by shaking 10 g of soil with 100 ml of K_2SO_4 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 Keeney 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 purporate 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 Analysis

Plant samples of pre-crops and main crops were separated into different parts as stems and roots and weighed 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 content. Dry matter content is calculated as follows: DM = (Dry weight / Fresh weight) *100. Moisture content (%) is calculated by subtracting DM from 100.

Fresh and dried biomass, root length and weight/plant were analyzed for both pre-crops. Primary and secondary nutrient content (N, P, K), fresh and dried biomass, and yield were analyzed for the main crops, tomato and zucchini.

For primary and secondary nutrient analysis, leaf samples were thoroughly washed twice with tap water and finally rinsed with distilled water, dried at 65°C for 5 days and ground.1 g of grounded leaf sample was weighed and wet-ashed with 10 ml of a mixture of nitric acid and perchloric acid. 8-10 ripe fruits were sampled, samples were cut into cubes and dried at 65°C. The dried fruit samples were grounded in a blender and wet-ashed.

5.3. Yield

Broccoli yield was recorded at each harvest as weight (g). Zucchini fruits were harvested two or three times a week, tomato fruits were harvested weekly. Each harvest was recorded as total yield (kg) per unit area for each subplot.

5.4. Quality Analysis

Diameter and length of the heads and stems (mm), weight of the heads (g), number of bracts, dry matter content and color were analyzed for broccoli heads.

Following parameters were determined to assess quality of tomato fruits: fruit weight (g) and volume (cm^3), ratio of marketable fruit (%), titratable acidity (% citric acid), soluble solids content (%) and Vitamin C ($mg.100g^{-1}$).

Fruit weight (g), fruit length (cm) and diameter (cm), dry matter and moisture contents (%), water soluble dry matter (%), titratable acidity and color were identified for zucchini fruit quality.

A Nippon FHR-1 penetrometer possessing a conical tip (base diameter 8 mm) was used to measure firmness for both main crops, and results were expressed in Newton (N).

Atago palette (Pr-101) refractometer was used to measure water soluble dry matter in juice for both main crops.

Vitamin C content was determined spectrophotometrically (Pearson, 1970).

5.5. Economic analysis

All the field operations (irrigation, tillage, worker wages, input and output amounts, unit prices) were recorded during the experiment. Gross margin was calculated with these data and a comparison was done between the treatments. Gross margin was calculated with the following equation:

Gross Margin (GM)= gross revenue- total variable costs

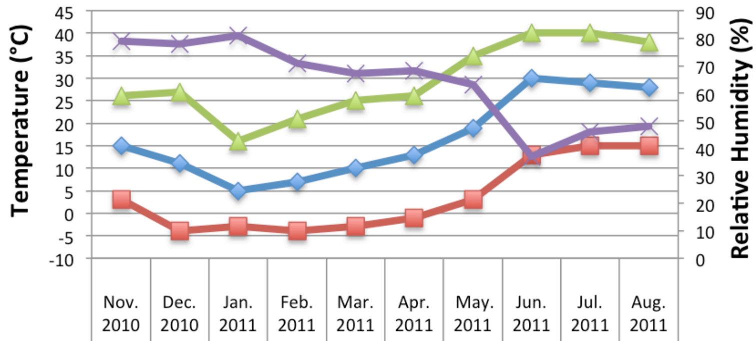
5.6. Statistical Analysis

The effect of tested variables was analyzed statistically using ANOVA with SPSS16. Effect of pre-crops was compared between vetch-wheat (main crop fertilized) and broccoli (main crop fertilized) treatments. Effect of vetch-wheat was tested alone (no additional fertilization (control)) and compared with the addition of compost and commercial fertilizer for the main crops treatments.

Chapter 3: Results and Discussion

1. Climatic Conditions

The climatic conditions occurring at the experimental field in Manisa-Turkey show a typical Mediterranean climate with warm and rainy winter, hot and dry summer. As could be seen in Figure 3 the growth cycle of the pre crops (November 2010-April 2011) overlapped with the rainy period. Relative humidity (RH) levels increased after November 2010 and remained over 60% until May 2011. After May 2011, average RH levels decreased constantly from June 2011 (RH average= 37%) to August 2011 (RH average= 48%).



	Nov. 2010	Dec. 2010	Jan. 2011	Feb. 2011	Mar. 2011	Apr. 2011	May. 2011	Jun. 2011	Jul. 2011	Aug. 2011
T average (°C)	15	11	5	7	10	13	19	30	29	28
T Min. (°C)	3	-4	-3	-4	-3	-1	3	13	15	15
T Max. (°C)	26	27	16	21	25	26	35	40	40	38
Relative Humidity (%)	79	78	81	71	67	68	63	37	46	48

Figure 3. Monthly average climatic data recorded during the experiment

In the pre-crops cycle, temperature decreased constantly from November 2010 (T average=15°C) to January 2011 (T average=5°C), and after January increased constantly to an average of 13°C in April. During the pre-crops cycle, maximum temperature reached to 27°C in December and a minimum of -4°C in December and February.

During broccoli production cycle, average temperatures were 15 °C and 11°C, in November and December, respectively. The average temperatures were favorable between September and November however in December average temperature was slightly lower than the optimum temperature preference of broccoli, which is between 15 to 24 °C (Smith, 2003).

The average temperature constantly increased from April (12°C) to June (30 °C) and then slightly decreased to 28 °C until the end of August. During the main crop cycle, average temperature in May (19 °C) was slightly lower than both pre-crops' optimum temperature preference, which is between 21-35 °C for zucchini (Molinar *et al.,* 1999) and 20-27°C for tomato (Hanson, 2001).

Between June and August average temperatures were slightly high for tomato on the other hand suitable for zucchini production.

2. Soil Properties

According to Table 2, soil organic matter content was low (1.28 %) in the beginning of the experiment. Incorporation of pre-crops statistically increased the organic matter content to a higher level according to the LSD test (Table 4). Organic matter levels were identified as moderate, 2.30 %, 2.86 % and 2.96% in T1, T2 and T3 plots, respectively on second sampling date (t1)(Fig.4). Regarding the statistical comparison of soil organic matter level on second sampling date (t1), there was no significant difference between treatments (Table 5). In previous experiments Özsoy (2010) and Ünal (2009) found no significance differences between vetch and broccoli treatments on the other hand Bilen (2008) found that vetch provides significantly more organic matter than the broccoli.

Table 2. Classification of soil organic matter content in soil, Thun *et al.* (1955).

Level	Very Low	Low	Modarate	High	Very high
O.M. (%)	<1	1-2	2-3	3-6	>6

After harvest of the main crops, the lowest and the highest organic matter contents were recorded in T1 (1.36%,) and T2 (2.34%,) after the harvest of main crops (t2), respectively (Table 4). Soil organic matter content was significantly decreased in T1 and T3. Second treatment, vetch and wheat mixture with additional fertilization showed a better performance in terms of organic matter and provided significantly higher organic matter then the other treatments at the end of the cycle.

Total N was identified as moderate according to the reference values presented in Table 3. In T2 and T3, total N content slightly increased from 0.11% to 0.14% between t0 and t2 but no significant differences were recorded between the sampling dates (Table 4) and treatments (Table 5). Normally higher N amounts are expected from the vetch-wheat mixture compared to broccoli, however the continuous rainfall between April and May could have reduced the increase in T2 and T3. Because on 8th April pre-crops were incorporated to soil and the soil was left without cover until the 10th May. On the other hand in T1 total N decreased from 0.11% to 0.09% even after the incorporation of broccoli, since broccoli heads were harvested and 15 ton.ha^{-1} of broccoli yield removes 80 kg N.ha^{-1} (Scaife 1995). After the main crops, total N level significantly increased by additional fertilization to 0.12% in T2 which is not significantly different from the initial level (Table 4). At the end of the experiment (t2) there was no significant difference between the treatments in terms of total N content and it was identified as very high in T2 and T3 and high in T1 according to the classification in Table 3.

Table 3. Classification of total nitrogen content in soil. Loue (1968)

Level	Very low	Low	Moderate	High	Very high
Total N(%)	<0.070	0.070-0.090	0.091-0.110	0.111-0.130	>0.130

In previous experiments of the study, Bilen (2008), Ünal (2009) and Özsoy (2010) found no significant differences between treatments in terms of total N after the incorporation of pre-crops.

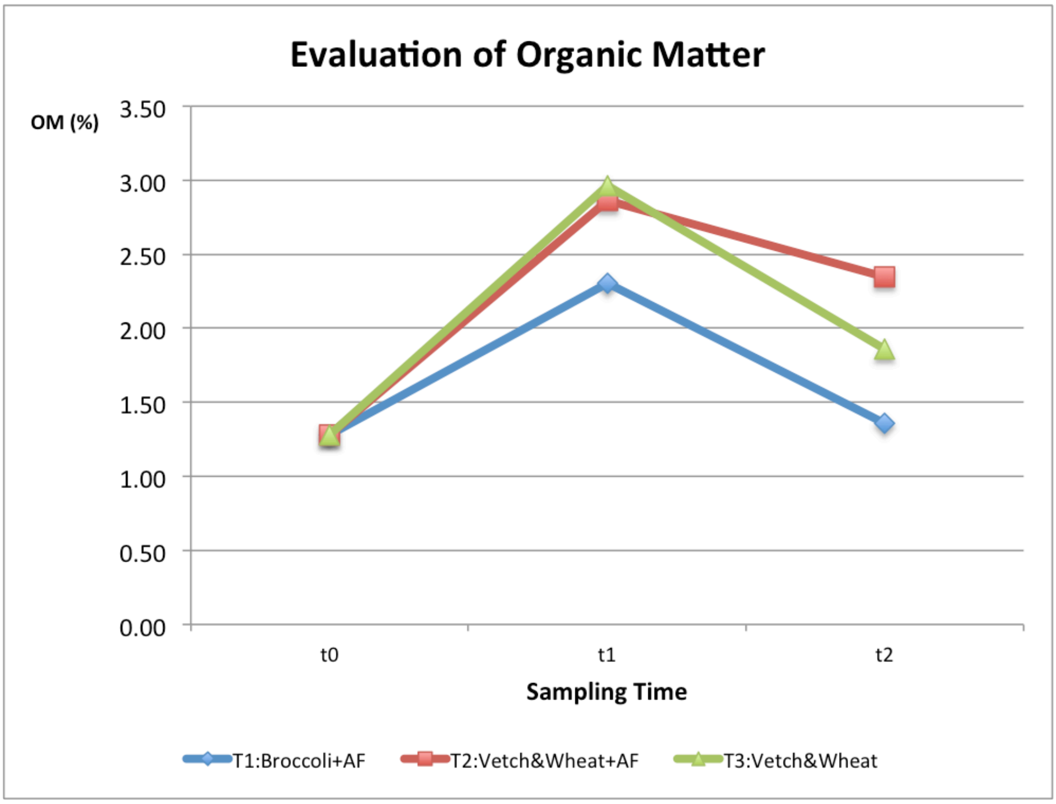
In a study carried under Mediterranean conditions, vetch and oil rapeseed were used in a rotation with maize. After the harvest of maize there was no significant difference between the treatments in terms of soil inorganic nitrogen content (Salmeron *et al., 2011).*

Table 4. Comparison of total N and organic matter during time, means with different letters are siginificantly different(* respresents significance at 0.05 level, ns: not significant.)

Organic Matter (%)			
Sampling Time	Broccoli+A.F	Vetch&Wheat+A.F	Vetch&Wheat
t0	1.28 b	1.28 b	1.28 b
t1	2.30 a	2.86 a	2.96 a
t2	1.36 b	2.34 a	1.86 b
LSD	*	*	*
Total N (%)			
Sampling Time	Broccoli+A.F	Vetch&Wheat+A.F	Vetch&Wheat
t0	0.11 ab	0.11	0.11
t1	0.09 b	0.13	0.13
t2	0.12 a	0.14	0.14
LSD	*	Ns	Ns

Table 5. Comparison of total N and organic matter between treatments on t1 and t2 (* represents significance at 0.05 level)

2nd Sampling (t1)		
Treatments	Organic Matter (%)	Total N (%)
T1: Broccoli+A.F	2.30	0.10
T2: Vetch&Wheat+A.F	2.86	0.13
Orthagonal Contrast	Ns	Ns
LSD	Ns	Ns
T2: Vetch&Wheat+A.F	2.86	0.13
T3: Vetch&Wheat	2.97	0.13
Orthagonal Contrast	Ns	Ns
LSD	Ns	Ns
3rd Sampling (t2)		
Treatments	Organic Matter (%)	Total N (%)
T1: Broccoli+A.F	1.36	0.13
T2: Vetch&Wheat+A.F	2.34	0.14
Orthagonal Contrast	0.17*	Ns
LSD	0.01*	Ns
T2: Vetch&Wheat+A.F	2.34	0.14
T3: Vetch&Wheat	1.86	0.14
Orthagonal Contrast	0.02*	Ns
LSD	0.02*	Ns



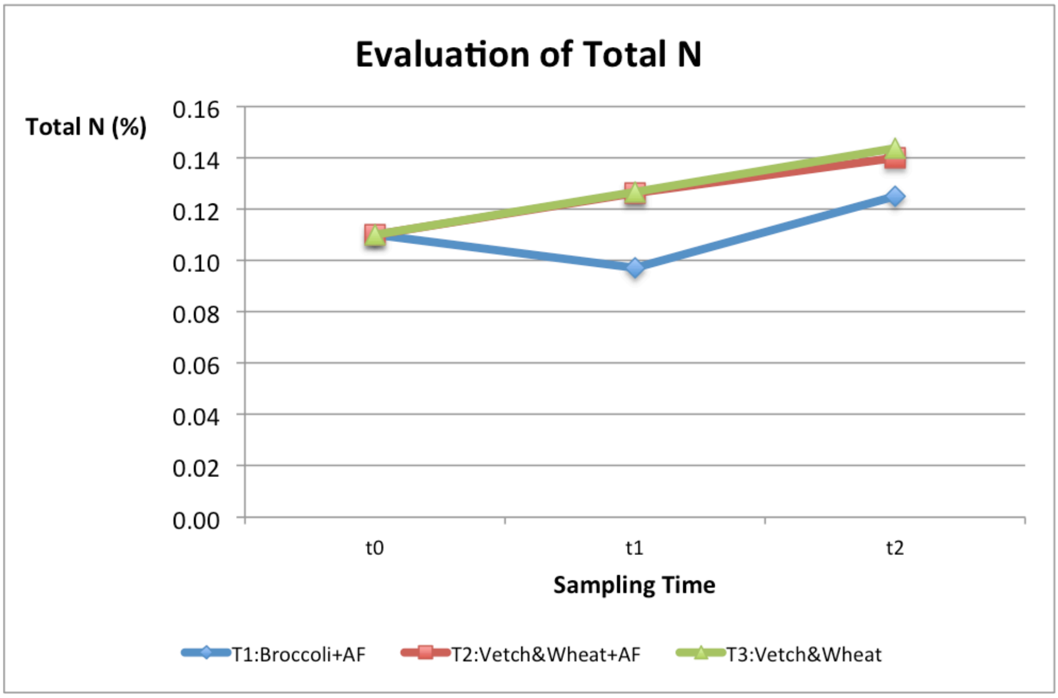


Figure 4. Evaluation of total N and organic matter during the experiment

3. Pre-Crops

3.1. Biomass Production

After harvest of broccoli main heads, 39.2 tons.ha^{-1} fresh biomass was left in the first treatment. According to Duncan test, there is a significant difference in comparison with the other treatments (Fig. 5). T2 produced 48 % more biomass than T1 however between T2 and T3 there is no significant differences as it was predicted, since all the applications and conditions were the same for T2 and T3 until the incorporation.

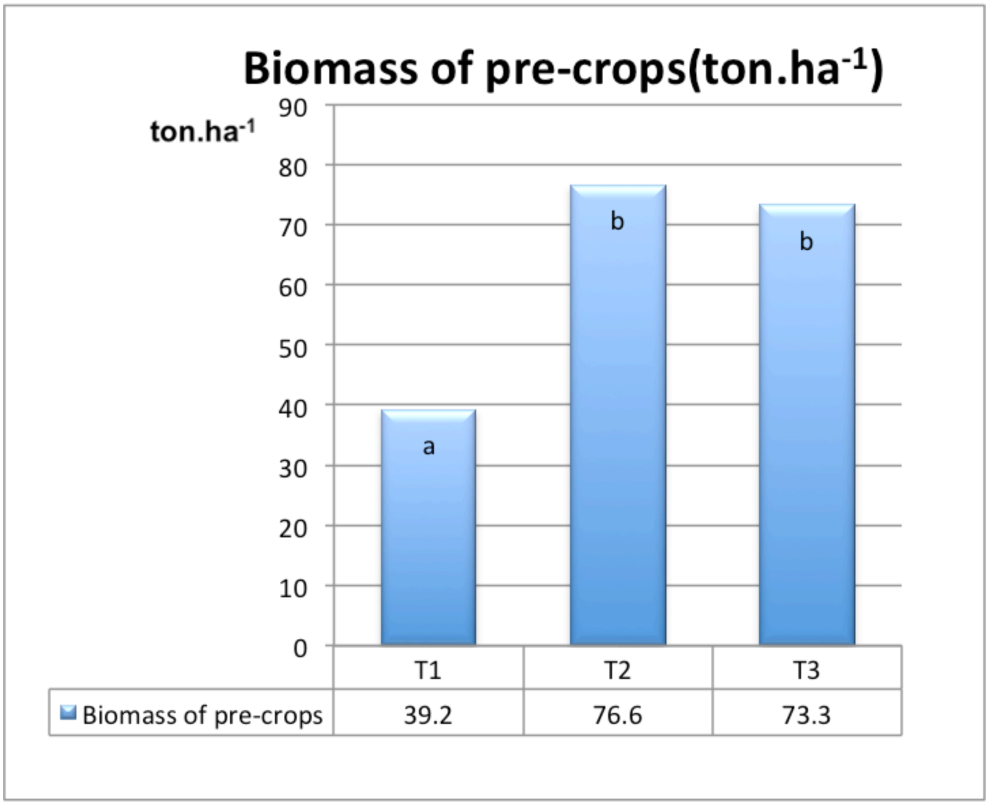


Figure 5. Biomass production of pre-crops, means with different letters are significantly different.(Duncan test, alpha=0.05).

Since there is no significant difference between T2 and T3, following numbers were calculated with mean values of the treatments. The incorporation of vetch wheat mixture provided 11.9 tons.ha^{-1} ha dry matter to the soil. Wheat stem and vetch stem provided 50% and 40% of the dry matter, respectively. Wheat stem provided 10% more dry matter than the vetch stem. Wheat root provided 9% of the dry matter and the rest 1% is supplied by the vetch root. These differences can be explained by the differences between plant and root growth of wheat and vetch. Contribution of wheat to dry matter incorporated per unit area is higher than vetch even if the ratio of seed mix is 4 kg of vetch to 1 kg wheat.

3.2. Broccoli Yield and Quality

Broccoli harvest started at the beginning of December 2010 and continued until the end of January 2011. Smaller heads on side shoots were not harvested due to the farmer's decision. Total amount of harvested main heads was 9.1 tons.ha^{-1}. In previous experiments of the study Bilen (2008) and Ünal (2009) was recorded higher broccoli yields, 13 tons.ha^{-1} and 38 tons.ha^{-1} respectively, under experimental conditions.

The average sizes of broccoli heads were in conformity with the sizes stated in UN/ECE standard (Table 6). The height and the diameter values were within the limits mentioned in the market standard.

Table 6. Quality parameters of broccoli heads.

	Height (cm)	Diameter (cm)	Weight (g)	Number of Bracts	Dry Matter Content (%)
T1	10.23	12.21	215.15	17.07	17.96
UN/ECE Standard	7.62 - 15.24	7.5 - 20			

4. Main Crops

4.1. Biomass Production

4.1.1. Zucchini

The amount of fresh biomass produced by zucchini was 18.3 tons.ha^{-1}, 28.5 tons.ha^{-1} and 27.8 tons.ha^{-1} respectively in plots T1, T2 and T3 (Fig. 6). In the first treatment, biomass production is approximately 35% less than the other two treatments, T2 and T3. However statistically there is no difference between the treatments according to the orthogonal contrast and LSD for the fresh biomass production due to the higher variation among replications (Table 7).

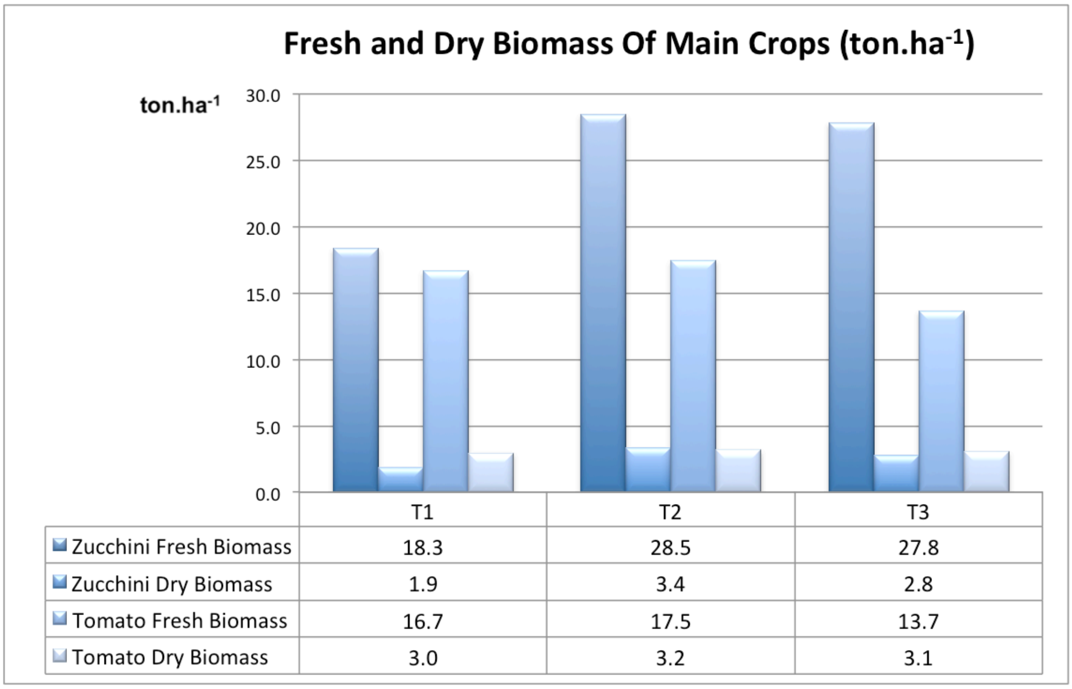


Figure 6. Biomass production of main crops

Dry biomass production was 1.9 tons.ha^{-1}, 3.4 tons.ha^{-1} and 2.8 tons.ha^{-1} in plots T1, T2 and T3, respectively. First treatment gave the lowest dry biomass, on the other hand, there is no significant differences between the treatments according to the orthogonal contrast and LSD values calculated because of higher variation among replications (Table 7).

4.1.2. Tomato

Tomato crops produced 16.7 3.4 tons.ha^{-1}, 17.5 tons.ha^{-1} and tons.ha^{-1} fresh biomass in T1, T2 and T3 plots, respectively (Fig. 6). Tomato plants had more vigorous growth in T2 and produced 6% and %21 more fresh biomass compared to the plants in T1 and T2, respectively. However according to the orthogonal contrast and LSD test there is no significant differences between the treatments in terms of fresh biomass because of higher variation among replications (Table 7).

For the dry biomass, the values are very similar between treatments, as could be seen in the Figure 6 and ranged between 3.0 – 3.2 tons.ha^{-1} and consequently the difference between the treatments is not significant.

Table 7. Statistical comparison of biomass production by main crops (A.F: Additional Fertilization, NS: Not significant, alpha=0.05)

	Zucchini		**Tomato**	
Pre-crop	Fresh Biomass (ton.ha^{-1})	Dry Biomass (ton.ha^{-1})	Fresh Biomass (ton.ha^{-1})	Dry Biomass (ton.ha^{-1})
T1: Broccoli+A.F	18.3	1.9	16.7	3.0
T2: Vetch&Wheat+A.F	28.5	3.4	17.5	3.2
Orthogonal Contrast	NS	NS	NS	NS
LSD	NS	NS	NS	NS
Fertilization	Fresh Biomass (ton.ha^{-1})	Dry Biomass (ton.ha^{-1})	Fresh Biomass (ton.ha^{-1})	Dry Biomass (ton.ha^{-1})
T2: Vetch&Wheat+A.F	28.5	3.4	17.5	3.2
T3: Vetch&Wheat	27.8	2.8	13.7	3.1
Orthogonal Contrast	NS	NS	NS	NS

4.2. Yield

4.2.1. Zucchini

Zucchini harvest started on June 27 and continued until August 10, 2011. The amount of zucchini at each harvested showed a steady increase until July 13 and decreased till the end of harvest (Fig. 7). The total of 18 harvests in the three treatments ranged between 37.9 – 40.1 tons.ha^{-1}.

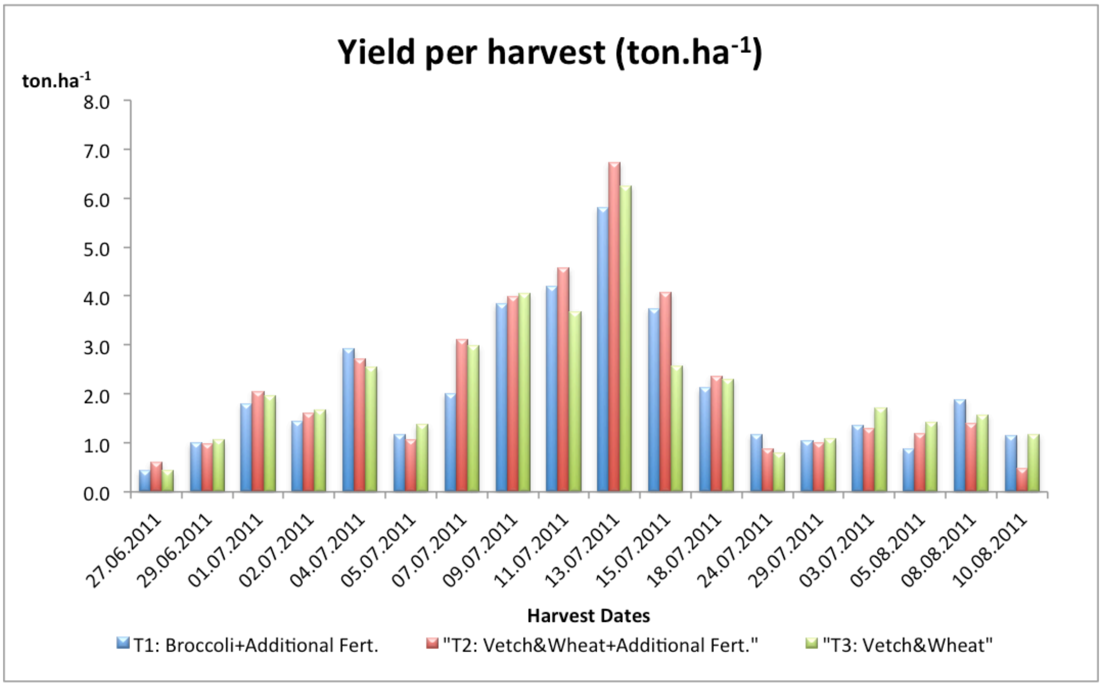


Figure 7. Zucchini yield per harvest (tons.ha^{-1})

According to the statistical comparisons, there is no significant difference between the treatments both for orthogonal contrast and LSD test in terms of total yield (Table 8). It is clear from the total yield value of T2 that the obtained yield is 5% and %3 higher than the T1 and T3. Besides, T2 treatment gave earlier crop (Fig. 7 and 9) being more concentrated around mid July.

Previous years study confirms these results, since the yield of zucchini was not significantly different in plots following broccoli and vetch grown as pre-crops at the experimental site (Bilen, 2008). On the other hand, Ngouajio and Mennan (2005) found that incorporation of sorghum, sudan grass, and rye provided higher cucumber yields than the incorporation of hairy vetch.

The organic zucchini seeds of 'cv. Sakız' were obtained from a seed company however the fruit shape was pear shaped during harvest maturity (Fig. 8). The fruit shape became cylindrical only when over-ripe and at larger sizes. The harvested fruit were marketed directly to a big retailer that refused most of the fruit due to its pear shape. Thus, marketable yield could not be calculated due to the shape defect of the selected cultivar.

Figure 8. Shape of zucchini fruits

Table 8. Comparison of total zucchini yield (A.F: Additional Fertilization, NS: Not significant, alpha: 0.05)

Treatments	Zucchini
Pre-crop	Total Yield (ton.ha^{-1})
T1: Broccoli+A.F	38.0
T2: Vetch&Wheat+A.F	40.1
Orthogonal Contrast	NS
LSD	NS
Fertilization	Total Yield (ton.ha^{-1})
T2: Vetch&Wheat+A.F	40.1
T3: Vetch&Wheat	38.7
Orthogonal Contrast	NS
LSD	NS

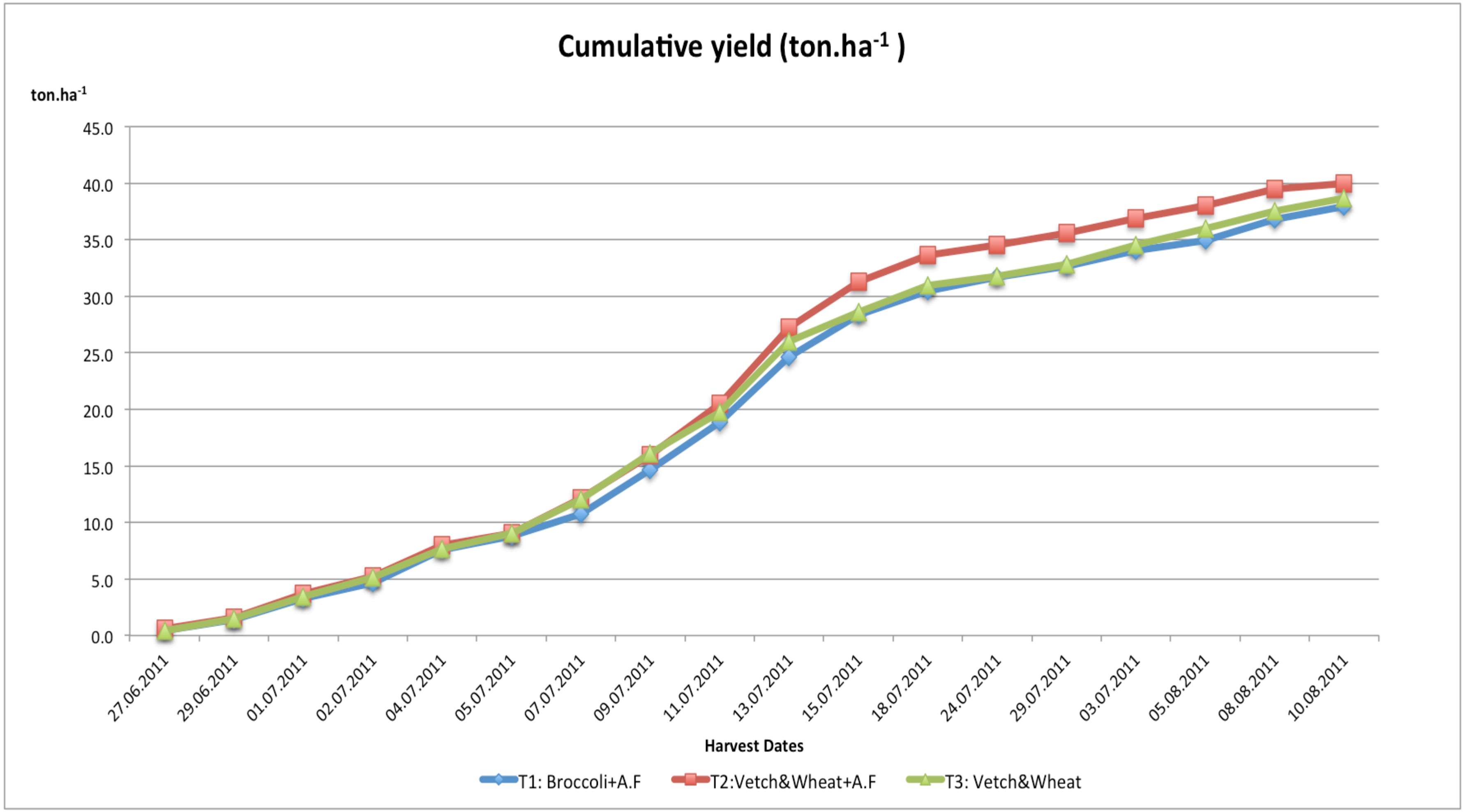


Figure 9. Cumulative yield (ton.ha^{-1}) of zucchini on 18 harvest dates (A.F: Additional Fertilization).

4.2.2. Tomato

Tomato fruits were harvested four times between 01 August and 24 August 2011. The highest amount was recorded during the third harvest in T1, T2 and T3 as 30.0, 26.7 and 18.8 tons.ha^{-1}, respectively (Fig. 10). According to this data, farmers can shift the date of transplanting seedlings in order to increase their supply during the period when demand peaks in the market.

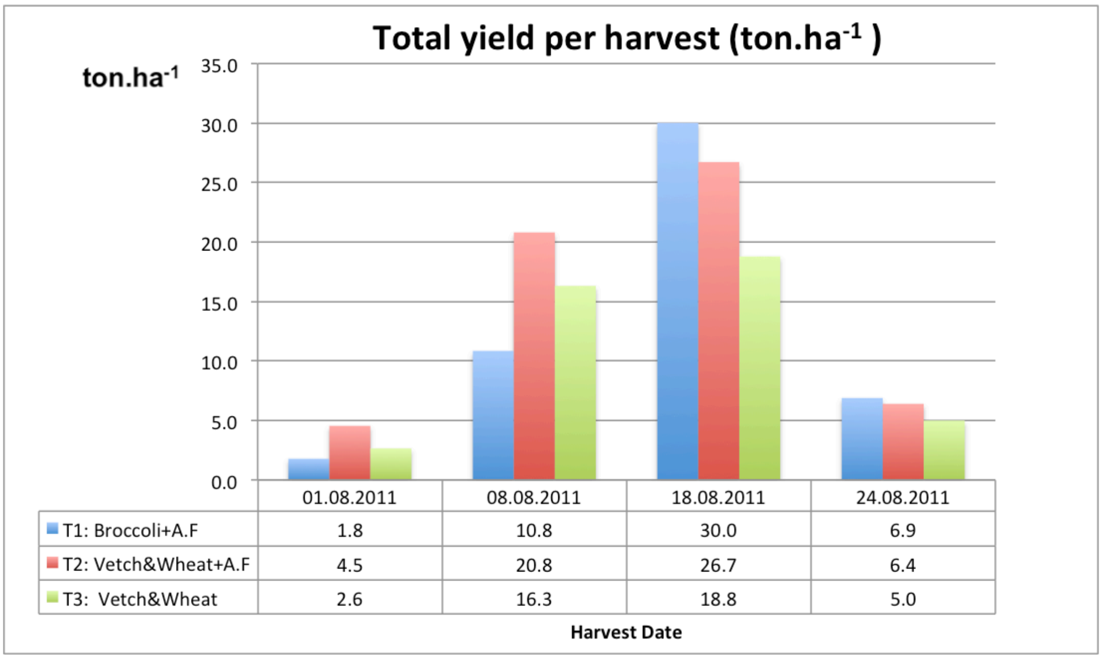


Figure 10. Total tomato yield per harvest (ton.ha^{-1})

Regarding the statistical analysis (orthogonal contrast and LSD test), the effect of pre-crops was not significant on total tomato yield. The effect of compost and commercial fertilizer applications had significant effect on tomato yield (alpha=0.01), second treatment provided 26 % higher total yield than the third treatment (Table 9). Since there is no significant difference between the pre-crop applications farmers can use both pre-crops with additional compost and commercial fertilizer to obtain higher yield. In a comparative trial of compost application with and without cover crop and mineral fertilizer application, treatments with compost (20 Mg.ha $^{-1}$) and compost (10 Mg.ha $^{-1}$) + Cover crop (hairy vetch) provided nearly the same tomato yield. In addition to this, both treatments provided significantly higher tomato yield than the mineral fertilizer treatment (168kg NH_4NO_3. ha $^{-1}$) (Carrera *et al*., 2007). Another experiment showed that the replacement of mineral fertilizers with compost appears to be a good solution for tomato crops in both open field and green house production (Blanco *et al*., 2011).
In the first experimental part of the project, Nazik (2007) found no significant effect on tomato yield between pre-crop treatments of vetch and broccoli and

concluded that the degradation of green manure is a long-term process and further effects could also be possible.

On the other hand, a two-years study concluded that the incorporation of hairy vetch and sub-clover performs statistically better than the non-legume species like rapeseed on potato tuber yield under Central Italy conditions possibly due to species and site differences (Campiglia *et al*., 2009).

Table 9. Comparison of total and marketable yield of the tomato (alpha=0.05,*significance)

Treatments	Tomato (ton.ha^{-1})	
Pre-crop	Total	Marketable
T1: Broccoli+A.F	49.5	42.8
T2: Vetch&Wheat+A.F	58.4	49.5
Orthogonal Contrast	ns	Ns
LSD	ns	Ns
Fertilization	Total	Marketable
T2: Vetch&Wheat+A.F	58.4	49.5
T3: Vetch&Wheat	42.7	36.6
Orthogonal Contrast	0.012*	0.014*
LSD	0.008*	0.008*

The ratio of marketable yield was 86 %, 84% and 85% in T1, T2 and T3, respectively. According to Table 9, there is no significant difference between the pre-crop treatments (T1 and T2) in terms of total and marketable yields. On the other hand, the application of compost and commercial fertilizer provided 26 % higher total and marketable yields.

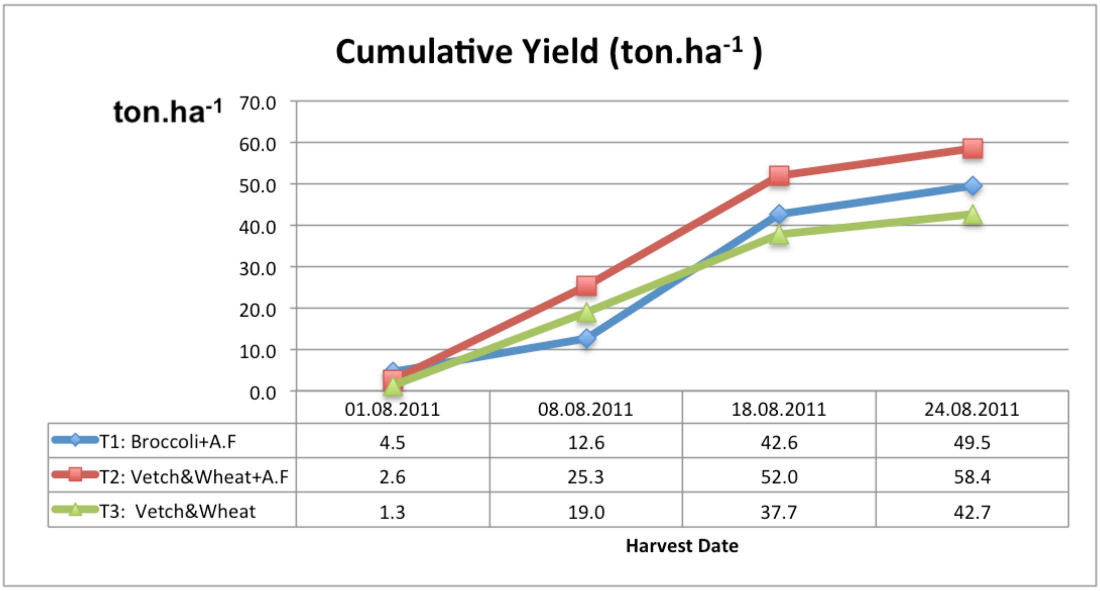


Figure 11. Cumulative yield of tomato obtained in three tested treatments.

4.3. Quality

4.3.1. Zucchini

The average length and diameter of the zucchini fruits were determined as 11.66 and 4.47 cm, respectively. Average fruit weight was calculated as 172.30 g (Table 10). The length and the weight of zucchini fruits are in conformity with Turkish Standards Institution standards (7-35cm length and 50-450g weight). According to orthogonal contrast and LSD test the fertilization treatment and the pre-crops did not affect most of the quality parameters significantly except color (hue angle). Similarly, no significant difference was found by Bilen (2008) for the quality parameters of zucchini in previous years' study conducted at the University experimental site in İzmir, Turkey.

Table 10: Comparison of quality parameters of zucchini fruits between treatments (alpha= 0.05)

TREATMENTS	Length (cm)	Diameter (cm)	Weight (g)	Firmness (N)	Dry Matter (%)
T1: Broccoli+ A.F	11.60	4.44	166.31	4.82	4.14
T2: Vetch&Wheat+A.F	11.38	4.57	174.96	4.96	4.14
Orthogonal contrast	ns	Ns	ns	ns	ns
LSD	ns	Ns	ns	ns	ns
T2: Vetch&Wheat+A.F	11.38	4.57	174.96	4.96	4.14
T3: Vetch&Wheat	11.99	4.40	175.63	5.13	4.45
Orthogonal contrast	ns	Ns	ns	ns	ns
LSD	ns	Ns	ns	ns	ns
Grand Mean	11.66	4.47	172.30	4.97	4.25
TREATMENTS	pH	WSDM (%)	Chroma	A/B	Titratable Acidity (%)
T1: Broccoli+ A.F	6.38	3.96	28.86	0.55	1.03
T2: Vetch&Wheat+A.F	6.45	4.21	28.54	0.54	1.12
Orthogonal contrast	ns	Ns	ns	ns	ns
LSD	ns	ns	ns	ns	ns
T2: Vetch&Wheat+A.F	6.45	4.21	28.54	0.54	1.12
T3: Vetch&Wheat	6.46	4.10	28.94	0.55	1.08
Orthogonal contrast	ns	ns	ns	ns	ns
LSD	ns	ns	ns	ns	ns
Grand Mean	6.43	4.09	28.78	0.55	1.08

As could be seen in Figure 12, hue angle values of the zucchini fruit color showed a significantly higher degree in the second treatment. Vetch and wheat mixture combined with fertilization application exerted a positive effect on hue values. According to the hue scale, zucchini fruits in T2 had lighter yellow color than the other treatments. As the fruit color turns to darker yellow, zucchini fruits are not marketable for Sakız cultivar due to the preference of the consumers.

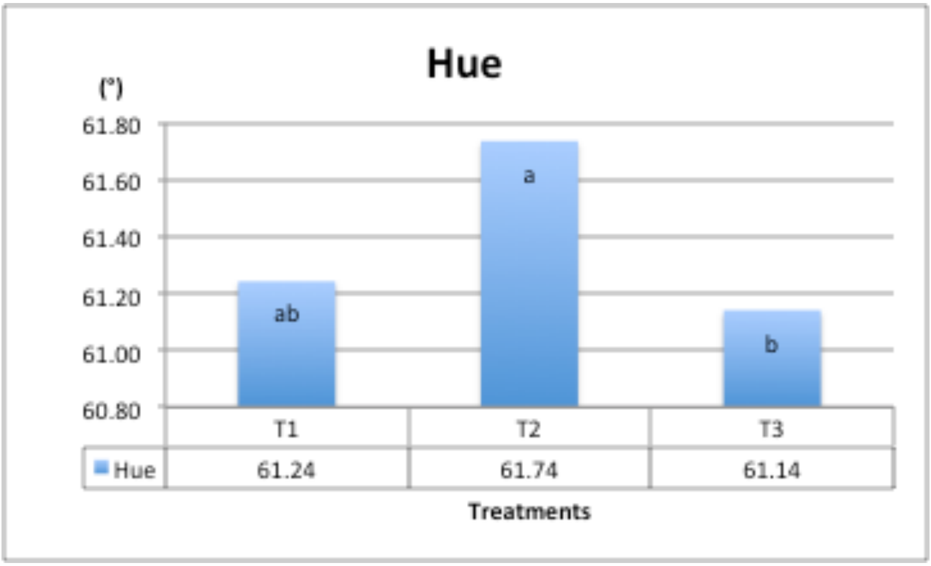


Figure 12. Comparison of hue angle values of zucchini fruits, means with different letters are significantly different (LSD test alpha: 0.05)

4.3.2. Tomato

The average fruit weight was determined as 236.45 g. The ratio of minimum to maximum diameter (cross diameter) was calculated as 0.73 less than 1 meaning that the cross section is cylindrical (Table 11). According to orthogonal contrast and LSD test most of the quality parameters were not affected significantly by fertilization treatment and the pre-crops except the water soluble dry matter (WSDM). In previous years' study carried by Nazik (2007), vetch and broccoli pre-crops similarly had no significant effects of on tomato fruit quality parameters.

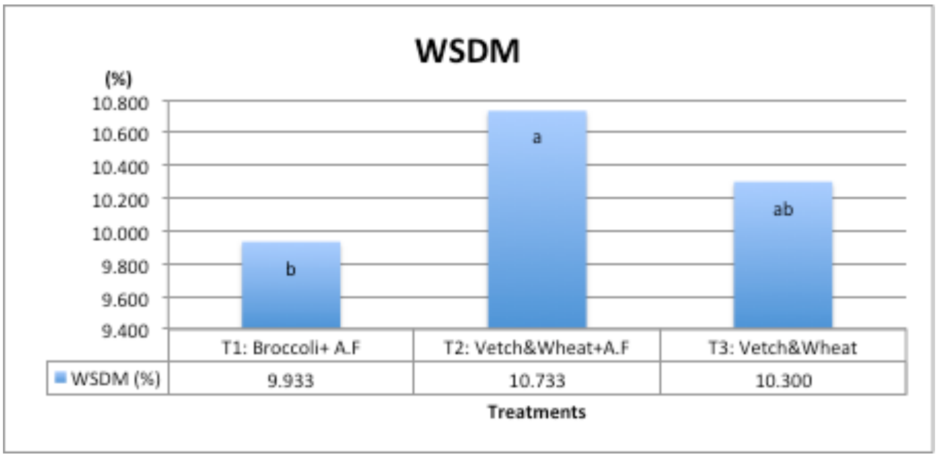


Figure 13. Comparison of water soluble dry matter content of tomato fruits, *means with different letters are significantly different (LSD test alpha: 0.05,* A.F: Additional fertilization)

As could be seen in Figure 13, second treatment yielded significantly higher percentage of WSDM, a significant quality attribute. Vetch and wheat mixture provided higher fruit WSDM content compared to broccoli grown as the precrop before tomato. In a sand culture trial of tomatoes, increases in the level of applied N increased the number of fruit set and increased the dry weight of roots, leaf, stem as well as the fruit. Fresh and dry weight of fruit were correlated with N from 1 up to 32 mmol L-I (Huett and Deltmann, 1988). Increased level of N at the second treatment could have resulted in elevated WSDM. Huett and Deltmann (1988) also recommend that in order to achieve optimum nutrition and hence maximum growth rates and quality of tomatoes under field conditions, the application of N and K fertilisers should be matched to the high demand which occurs over the fruit growth period. The decomposition of incorporated vetch+wheat biomass and aerial N fixed by vetch seem to provide all the necessary N and K required for an optimum yield and quality.

Table 11. Comparison of the quality parameters of tomato fruits between treatments (alpha: 0.05)

TREATMENTS	Weight (g)	Diameter min. (cm)	Diameter max. (cm)	Cross Diameter (min./max.)	Dry Matter (%)	Firmness (kg)
T1: Broccoli+ A.F	232.9	68.7	92.8	0.74	11.9	3.4
T2: Vetch&Wheat+ A.F	238.0	65.0	89.7	0.73	13.0	3.6
Orthogonal contrast	Ns	Ns	Ns	Ns	Ns	Ns
LSD	Ns	Ns	Ns	Ns	Ns	Ns
T2: Vetch&Wheat+ A.F	238.0	65.0	89.7	0.7	13.0	3.6
T3: Vetch&Wheat	238.4	66.6	92.5	0.7	12.3	3.6
Orthogonal contrast	Ns	Ns	Ns	Ns	Ns	Ns
LSD	Ns	Ns	Ns	Ns	Ns	Ns
Grand Mean	236.45	66.76	91.66	0.73	12.40	3.52
TREATMENTS	CHROMA	HUE	A/B	TA (%)	pH	Vitamin C (mg.100g^{-1})
T1: Broccoli+ A.F	72.4	119.0	1.2	0.4	9.2	26.6
T2: Vetch&Wheat+ A.F	79.7	119.0	1.2	0.3	9.2	23.6
Orthogonal contrast	Ns	Ns	Ns	Ns	Ns	Ns
LSD	Ns	Ns	Ns	Ns	Ns	Ns
T2: Vetch&Wheat+ A.F	79.7	119.0	1.2	0.3	9.2	23.6
T3: Vetch&Wheat	78.6	120.8	1.1	0.3	9.2	22.4
Orthogonal contrast	Ns	Ns	Ns	Ns	Ns	Ns
LSD	Ns	Ns	Ns	Ns	Ns	Ns
Grand Mean	76.89	119.61	1.17	0.35	9.18	24.17

5. Primary Nutrient Contents

5.1. Zucchini

Pre-crops and fertilization strategy had no significant effect on primary nutrient contents of zucchini fruits and leaf blade. However vetch-wheat mixture as pre-crop and application of compost and commercial fertilizer had a significant effect on N (%) content of the leaf petiole. In T2, leaf petioles accumulated 35% and 20% more N than T1 and T3, respectively (Table 12). Crop residues can release large amounts of mineral nitrogen in particular vegetable residues, which are rich in N such as Brassicas (Neve *et al*., 1998) however in the experiment nitrogen fixation of vetch and additional contribution of vetch wheat mixture biomass exceeded those released by broccoli residues. Huang *et al.* (2010) reported that in spinach, petiole Nitrate-N concentration and total amount of Nitrate-N accumulated in petiole were higher than in blade and highly correlated with fresh and dry shoot weight and total amount of water in shoots. Siminis *et al.* (1998) found elevated nitrate content in leaf petioles of tomato plants treated with humic substances (HS). Total N was 10 and 12% higher in leaves from tomato plants exposed to 5 and 50 mgl^{-1} HS respectively, compared to that from untreated plants. On the other hand, fruits harvested from treated plants had a reduced content in nitrate, ammonium and total N while K, Fe and Zn content was elevated. Fruit Ca, Mg and Mn contents remained unaffected by HS application. These findings puts forth the importance of the leaf N levels especially of leaf petiole in leafy vegetables however not at the same level for fruit vegetables as zucchini or tomato.

For the other nutrients (P, K, Ca and Mg) analyzed in leaf petiole, there was no significant differences between the treatments. In the previous study of the same project, Bilen (2008) found no significant difference between vetch and broccoli treatments in terms of zucchini fruit ash contents.

5.2. Tomato

In tomato fruits, pre-crops and fertilization strategy had no significant effect in terms of primary nutrient contents. Moreover, according to the statistical comparison of T1 and T3, using broccoli as pre-crop and application of compost and commercial fertilizer (T1) provided statistically higher P (0.30 %), Ca (0.15 %) and Mg (0.15 %) contents in tomato fruits compared to vetch-wheat mixture as a pre-crop without any fertilization (T3) (Table 12). Siminis *et al.* (1998) studied the effects of humic substances from olive tree leaves compost on nutrient accumulation and fruit yield in tomato (*Lycopersicon esculentun* cv Alexandros). Humic substances were found to enhance K, Ca, Mn, Zn and Fe accumulation in leaf petiole and laminae of tomato plants whereas no effect on Mg.

Pre-crops or additional fertilization had no significant effect on leaf N, P, K, Ca and Mg contents. On the other hand, regarding the statistical comparison of T1 and T3, broccoli as pre-crop and application of compost and commercial fertilizer (T1) provided statistically higher leaf P (0.16 %) content than vetch-wheat mixture as pre-crop without any fertilization (T3) (Table 12).

Results are in conformity with previous study. Nazik (2007) found that vetch and wheat as pre-crop had no significant effect on primary nutrient contents of tomato fruits and leaves.

The grand mean of tomato leaf N, P and K contents are found as 2.2%, 0.14% and 2.4%, respectively. These values are inadequate according to the reference values given by Alan (2005), since the optimum primary nutrients content of tomato leaves was reported as 4-5.5 % N, 0.40-0.65 % P and 3-6 % K.

Table 12. Primary nutrient contents of zucchini (fruits, leaf blade and leaf petioles), tomato (fruits and leaves), means with different letters are significantly different. (* Statistically different at 0.05 level, ns: not significant)

Zucchini Fruits					
	N (%)	P (%)	K (%)	Ca (%)	Mg(%)
T1	3.26	0.54	7.16	0.16	0.16
T2	4.50	0.44	4.52	0.15	0.16
T3	4.27	0.52	7.71	0.16	0.20
LSD	ns	Ns	Ns	ns	ns
Zucchini Leaf petiole					
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	1.51 b	0.23	15.85	1.65	0.41
T2	2.19 a	0.20	21.31	1.22	0.33
T3	1.75 b	0.20	17.91	1.76	0.41
LSD	*	Ns	Ns	ns	Ns
Zucchini Leaf blade					
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	3.42	0.25	3.79	4.17	0.92
T2	3.58	0.22	4.45	2.95	0.78
T3	4.01	0.27	4.92	3.41	0.67
LSD	ns	Ns	Ns	ns	Ns
Tomato Fruits					
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	2.24	0.30 a	5.33	0.15 a	0.15 a
T2	2.31	0.25 ab	4.90	0.13 ab	0.15 ab
T3	2.10	0.23 b	4.69	0.10 b	0.13 b
LSD	ns	*	Ns	*	*
Tomato Leaf					
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T1	2.23	0.16 a	2.38	3.77	0.75
T2	2.03	0.14 ab	2.09	3.77	0.81
T3	2.34	0.13 b	2.74	4.04	0.79
LSD	ns	*	Ns	ns	ns

6. Economical analysis

In this study gross margin was calculated for each treatment to compare the variable costs and total revenues of the different rotations and fertilization managements carried out. Even though the study was carried on a real farm, the economic study of this work could not be considered as farm conditions due mainly to the small total area of the experiment (0.1 ha), compared to the total farm surface. On this small areas of the experiment the fixed costs assessment was unattainable since almost all the agricultural operations and applications (sowing, transplanting, compost application…etc.) were done manually and thus excluding the use of machines usually required on big surfaces and real farm conditions. Therefore, the gross margin was calculated instead of the crop-budget. Moreover, the results of this economic analysis intend to give an idea to the farmer about the different treatments costs and revenues showing him the different evaluations and scenarios in order to choose what suites him better rather than to give him absolute values of revenues.

The results (Table 13) are presented in 100m² (widely used agricultural studies), since giving values per hectare is hazarded and reporting them to the actual surface of the experimental sub-plots is inappropriate. In addition to this, zucchini fruits were not marketed entirely, and revenues were calculated with the seasonal prices of zucchini fruits.

The highest and the lowest total gross margins were recorded in T3 (65.8 €./100m^2) and T1 (48.7 €./100m^2) respectively for zucchini as the main crop. Although the yield of treatments was similar, broccoli and zucchini rotation with additional fertilization (T1) showed lower total gross margin than the vetch-wheat mixture and zucchini rotation with additional fertilization (T2), mainly due to higher seedling cost. Additional fertilization strategy caused a reduction in the total gross margin due to the similar yields of T2 and T3.

The total gross margins were calculated as 44.3 €./100m^2 , 78.3 €./100m^2 and 34.5 €./100m^2 in T1, T2 and T3, respectively for tomato. Vetch-wheat mixture and tomato rotation with additional fertilization (T2) provided the highest total gross margin. According to this outcome, broccoli as pre-crop caused a decrease due to the low yield and higher seedling cost whereas; the additional fertilization strategy caused an increase in the total gross margin.

The highest total variable costs were recorded in the first treatment, broccoli-zucchini/tomato rotations with additional fertilization. This is primarily due to the high broccoli seedling costs.

The lowest total revenues were recorded in the third treatment, vetch and wheat mixture-tomato/zucchini rotations due to lower main crop yields.

Table 13. Economic analyses of three different treatments(€/100m^2)

Pre-crops	Broccoli	Vetch wheat mix.	Vetch wheat mix.
	T1	T2	T3
Revenues	€ 83.0	€ 0.0	€ 0.0
Variable Costs			
seed/seedling	€ 65.5	€ 1.4	€ 1.4
Fertilizers	€ 0.0	€ 0.0	€ 0.0
Authorized pesticides	€ 0.0	€ 0.0	€ 0.0
Water	€ 2.3	€ 0.0	€ 0.0
Labour	€ 25.7	€ 4.9	€ 4.9
Fuel	€ 6.0	€ 2.7	€ 2.7
Total variable cost	€ 99.5	€ 9.0	€ 9.0
Gross Margin	€ -16.5	€ -9.0	€ -9.0

Main crops	Zucchini			Tomato		
	T1	T2	T3	T1	T2	T3
Revenues	€ 149.2	€ 156.9	€ 152.0	€ 168.1	€ 194.6	€ 144.0
Variable Costs						
seed/seedling	€ 8.6	€ 8.6	€ 8.6	€ 52.4	€ 52.4	€ 52.4
Fertilizers	€ 6.8	€ 6.8	€ 0.0	€ 6.8	€ 6.8	€ 0.0
Authorized pesticides	€ 0.8	€ 0.8	€ 0.8	€ 3.5	€ 3.5	€ 3.5
Water	€ 10.9	€ 10.9	€ 10.9	€ 7.2	€ 7.2	€ 7.2
Labour	€ 51.0	€ 51.0	€ 51.0	€ 30.3	€ 30.3	€ 30.3
Fuel	€ 6.0	€ 6.0	€ 6.0	€ 7.0	€ 7.0	€ 7.0
Total variable cost	€ 84.0	€ 84.0	€ 77.2	€ 107.3	€ 107.3	€ 100.4
Gross Margin	€ 65.1	€ 72.9	€ 74.8	€ 60.8	€ 87.3	€ 43.5
Rotations	**Broccoli-zucchini**	**Vetch wheat-zucchini**	**Vetch wheat-zucchini**	**Broccoli-Tomato**	**Vetch wheat-Tomato**	**Vetch wheat-Tomato**
	T1	T2	T3	T1	T2	T3
Total revenues	€ 232.2	€ 156.9	€ 152.0	€ 251.1	€ 194.6	€ 144.0
Total variable costs	€ 183.5	€ 93.0	€ 86.2	€ 206.8	€ 116.2	€ 109.4
Total gross margins	€ 48.6	€ 63.9	€ 65.8	€ 44.3	€ 78.3	€ 34.5

Chapter 4: Conclusions and Recommendations

The effect of pre-crops was not significant on zucchini and tomato yield. Even if there is no significant difference between the pre-crop treatments, vetch and wheat mixture provided yields slightly higher than broccoli for both main crops. In addition to this, pre-crops had significant effect on water soluble dry matter in tomato fruit, however pre-crops had no effect on most of the fruit quality parameters, such as firmness, dry matter and titratable acidity contents of both zucchini and tomato crops.

Addition of compost and commercial fertilizer rich in potassium had a significant effect on tomato yield. Vetch and wheat mixture with compost and commercial fertilizer application provided higher tomato yield and earlier harvest than the unfertilized vetch-wheat mixture. Therefore vetch and wheat mixture-tomato rotation with an application of compost and commercial fertilizer can be suggested to the farmers under Mediterranean climatic conditions. On the other hand at the end of the cycle, this rotation provided the highest soil organic matter significantly different than the other treatments. Organic matter level was significantly elevated compared to the initial level.

Regarding to the marketable yield, zucchini fruits harvested were not entirely marketed due to the fruit shape of the selected cultivar. The retailer that the farmer was selling all her organic products refused to accept pear (bell) shaped zucchini. As experienced with zucchini, variety selection can be a major limitation since satisfaction of consumer’s demand is crucial for access to the market . If the open organic farmers’ market were the farmer’s marketing channel, pear shaped zucchini fruits would have no marketing problems since organic certification is still the most important parameter for the consumers purchasing from open organic markets.

Economically tomato following vetch-wheat mixture as green manure provided the highest gross margin. However this outcome cannot be generalized and recommended for bigger scale production or for different agroclimatic conditions but it can give an idea about the profitability of the tested rotations.

Moreover, agronomically the most recommended rotation was vetch and wheat mixture as pre-crop and tomato as the main-crop with additional application of compost and commercial fertilizer under Mediterranean conditions. The farmers can increase their profitability by preparing on-farm composts and enrich in potassium

Following recommendations could be made for the future on-farm researches:

The experiment should be established at larger scales to establish more replications. Similar trials can be performed with more farmers and site conditions.

The duration of the on-farm trial should be extended to evaluate the effect of tested pre-crops for a longer time span and with different main crops.

The market channel and the quality demand of the target market(s) need to be analyzed prior to the main crop selection both in terms of species and varieties.

A treatment with broccoli pre-crop without any fertilization should be added to see the necessity of fertilization for main crops.

For economical analysis crop budgeting should be calculated instead of gross margin so that results could be generalized.

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