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Performance of Wheat Varieties (*Triticum aestivum* L.) under Conservation Tillage Practices in Organic Agriculture

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Abstract

Field experiments were conducted to determine the effects of tillage systems and varieties on growth, yield and quality of wheat crop (*Triticum aestivum* L.). The experiments conducted at two sites were laid out in a split-plot design with four replicates, three main plots [conventional tillage (CT), no-tillage (NT) and minimum tillage (MT)] and four sub-plots ('Siette', 'Panifor', 'Myrto', 'Estero'). The soil porosity and total nitrogen were higher in soils subjected to conservation tillage systems (NT and MT) than under conventional tillage. There were no differences in root growth neither between the tillage systems nor among the varieties. Yield was influenced by the tillage system and variety. The highest grain yield (421-459 kg ha^{-1}) was found under the CT system with 'Siette', 'Myrto' and 'Estero' varieties. In contrast, the highest grain yield was observed under conservation tillage (NT and MT) with 'Panifor' variety. There were no significant differences between the tillage systems concerning the protein content and Zeleny value. In contrast, the highest Hagberg falling number was found with MT. Zeleny value was positively and significantly correlated with protein content. High flour quality, as demonstrated by high protein content and Zeleny value, and low Hagberg falling number, was produced in the 'Estero' variety.

Keywords: conventional tillage, Hagberg falling number, minimum tillage, no-tillage, quality, Zeleny value

Introduction

Conservation tillage covers a range of tillage practices which aim to conserve soil moisture and reduce soil erosion by leaving more than one-third of the soil surface covered by crop residues. Conservation tillage includes a shallow working depth without soil inversion, i.e. no tillage, or reduced or shallow tillage with tines or discs (Peigne *et al.*, 2007). Understanding the effects of conservation tillage practices on soil structure is critical for suitable soil management (Daraghmeh *et al.*, 2009). Conservation tillage (no-tillage and minimum tillage) systems generally improve soil organic C, plant-available water capacity, aggregation and soil water transmission (Bhattacharyya *et al.*, 2008). Alvarez (2005) reported that no differences in soil organic carbon (SOC) were found between reduced tillage (chisel, disc and sweep till) and no-tillage, whereas conventional tillage (mouldboard plough, disc plough) was associated with less SOC. Conservation tillage can be beneficial for soil, water and soil organic matter conservation in Mediterranean areas that are prone to soil erosion and where water availability for crops is the main factor for sustainability (Cantero-Martinez *et al.*, 2007). Soil organic matter is crucial for maintaining soil quality. Carbon sequestration in agricultural soils can contribute to offset-ting anthropogenic CO_2 emissions and also to enhancing soil fertility, soil water retention and crop production (Alvaro-Fuentes *et al.*, 2009).

Moreover, no-tillage is becoming increasingly attractive to farmers because it clearly reduces production costs relative to conventional tillage (DeVita *et al.*, 2007). No-tillage has been adopted worldwide as a strategy to reduce the negative effects of soil erosion brought about by conventional tillage (Cavalieri *et al.*, 2009). Adoption and successful implementation of no-tillage is strongly dependent on the farmer's knowledge of the technology involved in such a system.

Data obtained by other researchers (Bhattacharyya *et al.*, 2008; Mrabet, 2000; Sidiras *et al.*, 2001; Sip *et al.*, 2009) demonstrate the beneficial effects of conservation tillage on the yields of cereal crops in conventional farming. The success of conservation tillage in organic farming hinges on the choice of crop rotation to ensure weed and disease control and nitrogen availability (Bilalis *et al.*, 2001; Peigne *et al.*, 2007). Organic farmers are encouraged to adopt conservation tillage to preserve soil quality and fertility and to prevent soil degradation and compaction.

It is estimated that more than 95% of organic production is based on crop varieties that were bred for the conventional high-input sector. Recent studies have shown

that such varieties lack important traits required under organic and low-input production conditions. Some of the traits (e.g. semi-dwarf genes) that were introduced to address problems such as lodging in cereals in high-input systems were shown to have negative side-effects (lower protein content and poorer nutrient-use efficiency) on the performance of varieties under organic and low-input agronomic conditions (Lammerts van Bueren *et al.*, 2010; Li *et al.*, 2010). Specific breeding for organic systems may help reduce their yield gap relative to conventional systems by exploiting genotype × system interaction (Annicchiarico *et al.*, 2010). The main objective of this study was to evaluate the effect of tillage system on soil properties, growth, grain yield and quality of wheat crop. It has been intended to evaluate the performance of four wheat varieties under organic conditions.

Material and methods

Field trials

The experiment was repeated twice. A winter wheat crop (*Triticum aestivum* L.) was established in the experimental field of the Agricultural University of Athens (23°43′E, 34°58′N) in 2007. The soil was clay loam (29.8% clay, 34.3% silt and 35.9% sand) with pH 7.24, NO_3-N 12.4 mg kg^{-1} soil, P 13.2 mg kg^{-1} soil, K 201 mg kg^{-1} soil. Annual temperature and precipitation were 18.11°C and 420 mm, respectively. In parallel, a wheat crop was established in the Agrinio area (western Greece, Lat: 38°35′, Long: 21°25′) in 2008. The soil was a clay loam (24.9% clay, 61.2% silt, and 13.9% sand) with pH 7.4, organic matter 1.45%, EC 0.63 mS cm^{-1}, 0.152% total nitrogen and a sufficient supply of phosphorus (P Olsen 175 ppm) and potassium (632 ppm). Annual temperature and precipitation were 17.2°C and 955 mm, respectively. Some meteorological data of the experimental sites are presented in Fig. 1. The sites were managed according to organic agriculture guidelines (EC 834/2007).

The experiments were set up on an area of 820 m^2 (34 m × 24 m) according to the split-plot design with four

Fig. 1. Meteorological data (temperature: °C and precipitation: mm) for the experimental sites during the experimental periods (January-June).

replicates, three main plots (conventional tillage: CT, moldboard plowing at 20-25 cm, followed by one rotary hoeing at 5-10 cm; minimum tillage: MT, chiseling at 20 cm depth followed by one rotary hoeing at 5-10 cm; no-tillage: NT: no tillage, direct sowing (in the row, hand tilling (5 cm deep) was performed before wheat sowing) and four sub-plots (wheat varieties: 'Panifor', Ester, 'Myrto', 'Siete Serros'). The main-plot size was 250 m^2. This study was part of a long-term experiment started in 2005 and 2006, in Athens and Agrinio, respectively. At each site, the tillage treatments were repeated every year on the same plots. The crop cultivated before the wheat was vetch (*Vicia sativa* L. cv. 'Alexander'). Wheat was sown by hand in rows 18 cm apart at a depth of 3 cm. Wheat was sown on 21 November 2007 and 20 November 2008 at a rate of 220 kg ha^{-1}. Finally, weeds were controlled by hand at 60 and 120 days after sowing.

Sampling, measurements and methods

Total porosity of the soil was determined by 1-Db/Dp, where Dp is the particle density (2.5 g cm^{-3}) and Db is the soil bulk density. Soil bulk density was determined for each plot by taking undisturbed soil cores with 100 cm^3-cylinders from a depth of 0-10 cm. Three samples of 100 cm^3 per plot were taken [220 days after sowing (DAS)]. The undisturbed samples were finally oven dried at 100°C for 24 h to obtain soil dry mass and the soil bulk density was calculated as follow: Db=dry mass (g)/100 cm^3. The total nitrogen was determined by the Kjeldahl method (Bremner, 1960) using a Buchi 316 device in order to combust and extract the soil samples.

For the computation of height and tillers, 10 plants were randomly selected in each plot. Root samples were collected 75 DAS and from the 0-25 cm layer by using a cylindrical auger (25 cm length, 10 cm diameter) at the midpoint between successive plants within a row. For each sample, roots were separated from soil after standing for 24 h in water + $(NaPO_3)_6$ + Na_2CO_3. The root dry weight was then determined after drying one of the paired samples for 48 h at 70°C. For the determination of the density and diameter of roots, the root samples were placed on a high-resolution scanner using DT software (Delta-T Scan version 2.04; Delta-T Devices Ltd, Burrwell, Cambridge, UK).

The wheat seed yield also was determined by manually harvesting the plants in the two centre rows of each plot on 22nd of June 2008 and 20th of June 2009. 1000-grain weight was estimated by randomly taking 4×100 grains from each plot. For the computation of ear length ten ears per plot were measured. Grain protein (%) was calculated after multiplying Kjeldahl N by 5.7 (De Vita *et al.*, 2007). The grain nitrogen content was determined by the Kjeldahl method. α-Amylase activity (Hagberg falling number) was measured using the Hagberg recommended method (Hagberg, 1960; ISO-3093, 2004). Finally, the sedimentation test (Zeleny value) developed by ISO-5529
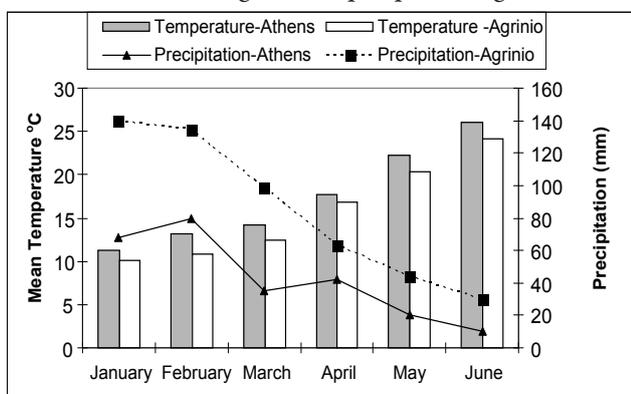
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was used for estimating the gluten strength of wheat grain (ISO-5529, 2007).

Statistical analysis

For calculating analysis of variance and comparisons of means, Statistica software (StatSoft 1996) was used. The LSD test was used to detect and separate the mean treatment differences. Correlation analyses were used to describe the relationships between growth parameters and yield components. All comparisons were made at the 5% level of significance.

Results and discussion

Soil properties

The lowest porosity (35.5-37%) and total N (0.121-0.133%) were found under CT (Tab. 1). There were also statistically significant differences between MT and NT systems. The highest porosity was observed under NT. Networks of biopores created by plant and animal activity might accumulate in untilled cropping systems (Wuest, 2001). Bilalis *et al.* (2009) observed that no-till management considerably influenced the improvement of the physical and chemical soil properties and increased the earthworm abundance. Data obtained by other researchers (Alvaro-Fuentes *et al.*, 2009; Bilalis *et al.*, 2010; Cantero-Martinez *et al.*, 2007; Cavalieri *et al.*, 2009; László *et al.*, 2007; Sidiras *et al.*, 2001; Tangyuan *et al.* 2009) clearly demonstrated the beneficial effects of conservation tillage (NT and MT) on soil structure and fertility. Daraghmeh *et al.* (2009) found that compared to conventional tillage,

Tab. 1. Influence of tillage system (conventional tillage: CT, minimum tillage: MT and no-tillage: NT) and wheat varieties ('Siette', 'Panifor', 'Myrto', 'Estero') on porosity (%) and total nitrogen (%) of soil, in Athens and in Agrinio

Varieties	Tillage system					
Porosity %	Athens			Agrinio		
	CT	NT	MT	CT	NT	MT
'Siette'	37	43.75	41	36.5	41	39
'Panifor'	35.5	43.5	39.75	35	42.25	39.75
'Myrto'	36.25	44	41	34.5	42	40.25
'Estero'	37.5	43	39.75	36	40.75	40
$LSD_{tillage}$ (P=0.05)	2.02 (F=8.04*)			1.69 (F=9.47*)		
$LSD_{varieties}$ (P=0.05)	2.45 (F=1.28ns)			1.45 (F=2.15ns)		
Total nitrogen %	CT	NT	MT	CT	NT	MT
'Siette'	0.123	0.161	0.139	0.103	0.145	0.127
'Panifor'	0.122	0.169	0.151	0.114	0.151	0.123
'Myrto'	0.121	0.155	0.175	0.109	0.144	0.130
'Estero'	0.133	0.154	0.164	0.106	0.139	0.135
$LSD_{tillage}$ (P=0.05)	0.02 (F=8.12*)			0.009 (F=10.34**)		
$LSD_{varieties}$ (P=0.05)	0.14 (F=1.33ns)			0.12 (F=1.78ns)		

The LSD (P=0.05) for tillage systems and wheat varieties are shown. F-test ratios are from ANOVA. *,** Significant at P=0.05 and P=0.01, respectively, ns: not significant

Tab. 2. Influence of tillage system (conventional tillage: CT, minimum tillage: MT and no-tillage: NT) and wheat varieties ('Siette', 'Panifor', 'Myrto', 'Estero') on diameter (mm) and density of wheat roots (cm cm^{-3}), in Athens and in Agrinio

Varieties	Tillage system					
Root diameter (mm)	Athens			Agrinio		
	CT	NT	MT	CT	NT	MT
'Siette'	1.05	0.90	1.14	0.98	0.89	1.05
'Panifor'	1.08	1.19	1.02	1.01	0.93	1.03
'Myrto'	0.78	0.84	1.07	0.82	0.77	0.85
'Estero'	0.96	0.98	1.15	0.91	0.86	0.89
$LSD_{tillage}$ (P=0.05)	0.29 (F=0.82ns)			0.16 (F=1.45ns)		
$LSD_{varieties}$ (P=0.05)	0.21 (F=0.74ns)			0.14 (F=1.68ns)		
Root density (cm cm^{-3})	CT	NT	MT	CT	NT	MT
'Siette'	3.68	3.32	3.71	3.73	3.67	3.81
'Panifor'	3.17	3.57	3.34	3.24	3.37	3.56
'Myrto'	2.48	3.62	3.00	2.67	2.78	3.08
'Estero'	2.56	2.98	2.86	2.78	3.12	2.98
$LSD_{tillage}$ (P=0.05)	0.63 (F=0.24ns)			0.45 (F=1.58ns)		
$LSD_{varieties}$ (P=0.05)	1.15 (F=0.48ns)			0.50 (F=6.56˙)		

The LSD (P=0.05) for tillage systems and wheat varieties are shown. F-test ratios are from ANOVA. *Significant at P=0.05, ns: not significant

reduced tillage improved soil structure through a combination of increased soil organic matter, reduced soil bulk density and increased proportion of larger aggregates. In addition, Sasal *et al.* (2006) found that total porosity under chisel plough was higher than under NT. Moreover, there were no significant differences between the wheat varieties concerning the soil properties. The maintenance of good soil physical conditions is extremely important to ensure satisfactory crop growth and high yields.

Wheat growth and yield

Concerning the emergence percentage, there were no significant differences between treatments. Moreover, there were no significant differences in root growth (root density and diameter) between CT, NT and MT systems (Tab. 2). In comparison, Munoz-Romero *et al.* (2010) found that the root length was greater under NT than under CT for most growth stages and depths. In contrast, the root diameter was not significantly affected by tillage treatments. Moreover, there were no significant differences in root growth between wheat varieties at the Athens site (Tab. 2).

The lowest height (Tab. 3) was found under NT. 'Estero' variety had lower height in comparison to the other varieties ('Siette', 'Panifor', 'Myrto'). The highest number of tillers was found under conservation tillage systems (NT and MT). There were no significant differences in tillering and ear length between wheat varieties (Tab. 3 and 4). In contrast, 'Estero' and 'Myrto' gave higher 1000-grain weights in comparison to the other varieties. The highest 1000-grain weight was found under CT. In comparison, De Vita *et al.* (2007) found that the highest 1000-grain weight was obtained under NT.

Tab. 3. Influence of tillage system (conventional tillage: CT, minimum tillage: MT and no-tillage: NT) and wheat varieties ('Siette', 'Panifor', 'Myrto', 'Estero') on height (cm) and tillers per plant of wheat, in Athens and in Agrinio

Varieties	Tillage system					
Height (cm)	Athens			Agrinio		
	CT	NT	MT	CT	NT	MT
'Siette'	85.52	73.3	79.97	86.45	76.34	82.31
'Panifor'	80.47	72.8	80.8	81.03	74.23	81.34
'Myrto'	79.62	75.1	78.8	79.34	76.02	76.23
'Estero'	71.17	69.82	62.40	72.56	71.09	73.45
LSD$_{tillage}$ (P=0.05)	3.45 (F=6.67*)			2.13 (F=10.56**)		
LSD$_{varieties}$ (P=0.05)	2.13 (F=21.25***)			1.47 (F=33.49***)		
Tillers per plant	CT	NT	MT	CT	NT	MT
'Siette'	5.37	14.12	13	9.56	11.23	10.97
'Panifor'	7.25	13.37	13.62	8.89	12.01	11.45
'Myrto'	4.12	13.15	12.87	9.23	10.95	11.23
'Estero'	8.87	13.12	13.37	9.52	11.05	10.78
LSD$_{tillage}$ (P=0.05)	0.23 (F=77.73***)			0.88 (F=11.21**)		
LSD$_{varieties}$ (P=0.05)	4.32 (F=1.67^{ns})			2.04 (F=3.49^{ns})		

The LSD (P=0.05) for tillage systems and wheat varieties are shown. F-test ratios are from ANOVA. *, **, *** Significant at P=0.05, P=0.01 and P=0.001, respectively, ns: not significant

Tab. 4. Influence of tillage system (conventional tillage: CT, minimum tillage: MT and no-tillage: NT) and wheat varieties ('Siette', 'Panifor', 'Myrto', 'Estero') on 1000-grain weight (g) and ear length of wheat, in Athens and in Agrinio

Varieties	Tillage system					
1000-grain weight (g)	Athens			Agrinio		
	CT	NT	MT	CT	NT	MT
'Siette'	43.20	39.92	40.46	43.74	41.03	41.46
'Panifor'	43.42	41.04	41.44	43.53	41.76	41.54
'Myrto'	45.55	41.69	42.92	45.76	42.49	42.73
'Estero'	46.87	41.72	43.28	45.73	42.72	43.45
LSD$_{tillage}$ (P=0.05)	0.18 (F=10.96**)			0.34 (F=7.34*)		
LSD$_{varieties}$ (P=0.05)	0.34 (F=12.94***)			0.44 (F=10.43**)		
Ear length (cm)	CT	NT	MT	CT	NT	MT
'Siette'	9.93	9.57	9.97	9.73	9.61	9.59
'Panifor'	9.70	9.82	9.65	9.78	9.76	9.87
'Myrto'	9.82	10.30	10.31	9.65	9.87	9.71
'Estero'	9.70	9.42	10.05	9.74	9.63	9.67
LSD$_{tillage}$ (P=0.05)	0.76 (F=0.81^{ns})			0.45 (F=1.34^{ns})		
LSD$_{varieties}$ (P=0.05)	1.22 (F=1.29^{ns})			0.56 (F=2.12^{ns})		

The LSD (P=0.05) for tillage systems and wheat varieties are shown. F-test ratios are from Anova. *, **, *** Significant at P=0.05, P=0.01 and P=0.001, respectively, ns: not significant

Yield was influenced by both the tillage system and variety (Tab. 5). The highest grain yields were found under the CT system (421-459 kg ha^{-1}) with 'Siette', 'Myrto' and 'Estero' varieties. In contrast, for the 'Panifor' variety, the highest grain yield was observed under conservation tillage (NT and MT). Munoz-Romero *et al.* (2010) reported that under rain-fed Mediterranean Vertisol, wheat pro-

Tab. 5. Influence of tillage system (conventional tillage: CT, minimum tillage: MT and no-tillage: NT) and wheat varieties ('Siette', 'Panifor', 'Myrto', 'Estero') on yield (kg ha^{-1}) and protein content (%) of wheat, in Athens and in Agrinio

Varieties	Tillage system					
Yield (kg ha^{-1})	Athens			Agrinio		
	CT	NT	MT	CT	NT	MT
'Siette'	421	399	360	414	388	365
'Panifor'	297	363	380	302	374	384
'Myrto'	432	380	334	427	390	345
'Estero'	459	397	430	448	384	426
LSD$_{tillage}$ (P=0.05)	25.32 (F=4.45*)			21.02 (F=6.37*)		
LSD$_{varieties}$ (P=0.05)	19.29 (F=4.63*)			14.34 (F=7.63*)		
Protein content %	CT	NT	MT	CT	NT	MT
'Siette'	11.43	11.85	11.15	11.12	11.24	11.18
'Panifor'	11.81	12.14	12.22	11.72	11.83	11.78
'Myrto'	12.02	12.38	12.62	11.89	12.12	12.21
'Estero'	12.96	12.92	13.22	12.45	12.62	12.69
LSD$_{tillage}$ (P=0.05)	1.02 (F=0.48^{ns})			0.66 (F=1.23^{ns})		
LSD$_{varieties}$ (P=0.05)	0.78 (F=13.49***)			0.44 (F=21.09***)		

The LSD (P=0.05) for tillage systems and wheat varieties are shown. F-test ratios are from Anova. *, *** Significant at P=0.05 and P=0.001, respectively, ns: not significant

ductivity is greater under NT due to better root system development. Moreover, De Vita *et al.* (2007) observed that the superior effect of NT on wheat yield in comparison to CT was due to lower water evaporation from soil combined with enhanced soil water availability. Sip *et al.* (2009) reported that the reduced tillage system combined with high input level delivered a yield advantage for all the wheat varieties tested.

Wheat quality

The assessment of wheat flour quality is a great importance for the wheat industry. High quality wheat grains are required for the milling and baking industries. Several physicochemical tests are employed in quality evaluation of wheat. Protein content, Zeleny sedimentation test and Hagberg falling number method are used to access the quality of wheat flours (Colombo *et al.*, 2008; De Vita *et al.*, 2007; Mares and Mrva, 2008). The sedimentation index (Zeleny test) measures the sedimentation volume of a suspension of flour in dilute lactic acid. Colombo *et al.* (2008) reported that the Zeleny test value was strongly correlated with bread loaf volume.

The Hagberg falling number test is a widely accepted, rapid test for determining the α-amylase activity of wheat. As the amount of enzyme activity increases, the falling number decreases. Many countries use the falling number method at grain receival and as a component of trade specifications. Hagberg falling numbers above 250, 300, or in some cases 350, sec are required for inclusion of delivered grain in high-quality grades depending on the standards set by the wheat industries (Mares and Mrya, 2008). Low values of Hagberg falling number cause loaves to be dis-

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Tab. 6. Influence of tillage system (conventional tillage: CT, minimum tillage: MT and no-tillage: NT) and wheat varieties ('Siette', 'Panifor', 'Myrto', 'Estero') on Zeleny value (cm^{-3}) and Hagberg falling number (sec) of flour, in Athens and in Agrinio

Varieties	Tillage system					
Zeleny value (cm^{-3})	Athens			Agrinio		
	CT	NT	MT	CT	NT	MT
'Siette'	19.75	19.5	19.75	25.67	25.34	25.78
'Panifor'	20.25	20.75	20.5	24.97	24.79	24.61
'Myrto'	21.5	22	20.75	25.88	25.31	25.89
'Estero'	23.25	24.25	23	25.44	25.17	25.46
LSD$_{tillage}$ (P=0.05)	1.54 (F=0.42^{ns})			1.08 (F=2.42^{ns})		
LSD$_{varieties}$ (P=0.05)	1.14 (F=12.42***)			1.23 (F=2.34^{ns})		
Hagberg falling number (sec)	CT	NT	MT	CT	NT	MT
'Siette'	437	453	474	324	315	328
'Panifor'	447	438	475	356	367	362
'Myrto'	438	434	447	318	323	312
'Estero'	403	408	423	317	309	298
LSD$_{tillage}$ (P=0.05)	4.87 (F=32.48**)			23.02 (F=5.48*)		
LSD$_{varieties}$ (P=0.05)	4.23 (F=33.23***)			50.24 (F=2.63^{ns})		

The LSD (P=0.05) for tillage systems and wheat varieties are shown. F-test ratios are from Anova. *, *** Significant at P=0.01 and P=0.001, respectively, ns: not significant

coloured, sticky and of poor texture. High protein concentration is required to impart strength to dough, allowing it to trap the CO_2 gas produced during fermentation (Smith and Gooding, 1999).

There were no significant differences in protein content between tillage systems in the present study (Tab. 5). In contrast, De Vita *et al.* (2007) reported that the highest protein content was obtained under CT (15.5-19.6% for CT *versus* 11.4-14.7% for NT). In Athens, the highest Hagberg falling number (Tab. 6) was found under MT. The 'Estero' variety had the lowest Hagberg falling number (403-423 sec) in comparison to the other varieties ('Siette', 'Panifor', 'Myrto'). There were no significant differences in Zeleny sedimentation value between tillage systems (Tab. 6). The Zeleny value had positive and significant correlation with protein content (r=0.45, P<0.01) in agreement with Colombo *et al.* (2008). Gursoy *et al.* (2010) found that tillage had a significant effect on grain yield and test weight, but did not significantly influence protein content and sedimentation. The 'Estero' variety had the highest Zeleny sedimentation value (23-24.25 cm³) in comparison to the other varieties ('Siette', 'Panifor', 'Myrto'). Hagberg falling number had negative and significant correlation with protein content and Zeleny value (r=-0.54, P<0.001 and r=-0.35, P<0.05, respectively). Grain quality is a complex characteristic that depends on a number of factors such as genotype and location (Colombo *et al.*, 2008; Kilic and Yagbasanlar, 2010; Zecevic *et al.*, 2009). Hagberg falling number is almost exclusively influenced by environment and genotypic main effects (Grausgruber *et al.*, 2000).

In Agrinio, concerning the wheat quality (Hagberg falling number and Zeleny value), there were no significant differences between treatments. The Hagberg falling number and Zeleny value in Athens were always higher than those in Agrinio. The main reason for lower wheat quality in Agrinio may be attributed to precipitation there during the harvest period. Pre-harvest sprouting and high α-amylase activity are the most serious problems for wheat production in some areas. It has become more frequent for wheat to be exposed to continuous rain for several days at harvest time (Yanagisawa *et al.*, 2005).

Conclusions

Our results indicate that **high quality flour (high protein content and Zeleny value and low Hagberg falling number)** was produced by the 'Estero' variety. Comparing the four varieties, it has been found that the 'Panifor' variety cultivated under the conservation tillage had higher yield. In contrast, the highest grain yield was found under the CT system with 'Siette', 'Myrto' and 'Estero' varieties. Moreover, there were no significant differences between the tillage systems concerning the protein content and Zeleny value. Finally, reducing tillage intensity improved the Hagberg falling number of wheat flour.

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