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Long-term yield patterns for continuous winter wheat cropping in northern Greece

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Abstract

Continuous winter wheat (*Triticum aestivum* L.) cropping is a common practice for many growers in Greece, particularly in soils with low fertility or non-irrigated fields where other crops cannot grow profitably. The effect of continuous cropping on grain yields of wheat grown under the same conventional tillage practices for 25 years was studied in four soils of northern Greece. Grain yields varied considerably from year to year, regardless of soil type, showing a high temporal variability. Grain yields from the sandy loam and the clay soil were the most unstable across years compared with those from the clay loam and the sandy clay loam soil, which showed lower variability in time. Grain yields from the sandy loam soil showed a high correlation with rainfall during March to May ($r = 0.71$), whereas grain yields from the clay soil showed a high correlation with total rainfall during growing season ($r = 0.89$). Grain yields of the clay loam and the sandy clay loam soil appeared to depend on rainfall less than yields of the other two soils. On the average, grain yield was much lower in the sandy loam and the clay soil (1.94 and 2.46 Mg ha^{-1}, respectively) than in the clay loam and the sandy clay loam soil (3.48 and 3.72 Mg ha^{-1}, respectively) showing a dependence of wheat yield on soil type. Despite the high temporal variability of grain yields, no significant trends towards yield decline were observed for any of the soils studied. In addition, no significant differences were detected in soil pH values and organic matter content at the middle or at the end of the experiment. Given that annual fertilization is maintained and weeds are controlled effectively, it could be concluded that continuous wheat cropping may be practiced for many years without significant yield decline or significant change in soil pH and organic matter content.

Keywords: Conventional tillage; Monoculture; Yield stability

1. Introduction

Winter wheat (*Triticum aestivum* L.) is the principal cereal grain crop used for food consumption all over the world, and an important commodity in the global grain market. It can grow under many different topographic and soil conditions, and shows a good adaptability to various climatic conditions. It is, therefore, a suitable option particularly for soils with low fertility or non-irrigated fields where other crops cannot grow profitably.

Winter wheat is a major crop for agricultural production in Greece. A total area of 850,000 ha was grown with winter wheat in 2004 (FAOSTAT, 2004). A large proportion of this land consists of poor or non-irrigated fields, where more productive crops such as corn, cotton or sugarbeet become less profitable than winter wheat. Consequently, continuous wheat has been the primary cropping system used by many farmers in Greece, particularly where crop diversity is constrained by physical or economical factors. Under these conditions, the ability to minimize yield losses from the use of monoculture can provide the best option to increase profitability, and thus wheat monoculture is frequently considered as the most competitive ‘rotation’ from an economical point of view (Sieling et al., 2005). This practice, however, is often associated with several disadvantages, such as increased weed populations, greater proliferation of pests and diseases, and less efficient use of water or nutrients, which all can reduce crop yields.

Cropping systems can influence crop yields as crops grown in previous years can affect parameters which determine subsequent plant growth. In general, when a crop is continuously grown in an area, lower yield may be observed due to limited root growth or activity. In particular, yield losses in continuous cropping can be attributed to various mechanisms such as exhaustion of residual soil water and nutrients, increased weed populations, proliferation of certain pathogens, reduced transformation of

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nutrients due to lower activity of soil microorganisms, which affect nutrient efficiency (Lindwall et al., 1995; Berzsenyi et al., 2000; Garrido and López-Bellido, 2001; Nielsen et al., 2002).

Several studies have reported yield reduction after continuous wheat cropping, compared with most of the examined rotation sequences (Christen et al., 1992; Hannah and O'Leary, 1995; Dalal et al., 1998; Gan et al., 2003; Huang et al., 2003). Wheat grain yields were decreased considerably in the third year of continuous cropping in Iran, which was attributed to the adverse effects of continuous cropping and weeds (Bahrani et al., 2002). Twenty-five years of continuous wheat cropping in India, with only nitrogen applied, reduced wheat grain yields to almost zero (Sharma and Subehia, 2003). Wheat following wheat yielded about 0.9 and 1.9 Mg ha^{-1} less in the second and the third year, respectively, compared with wheat grown after oilseed rape (Sieling et al., 2005). Similar yield reduction has been observed for continuously grown barley. For example, barley grown after oats or rapeseed produced a higher dry weight and a larger number of tillers per m^2 than barley following wheat or barley (Christen and Sieling, 1993). Similarly, barley yields were reduced in a 3-year continuous monocropping system mainly because of the increased infections by soil-borne viruses (Delogu et al., 2003). Yau et al. (2003) studying a barley–legume rotation concluded that barley monoculture is a non-sustainable cropping system, and barley grain yields could be increased and sustained by including legumes in the rotation.

On the other hand, several studies have shown that continuous cropping can be used in cereal production without significant yield losses. For example, Jones and Singh (2000) concluded that in the medium term continuous barley cultivation is not necessarily a non-sustainable cropping system given that adequate annual fertilization is maintained. Continuous wheat cropping for 4 years did not appear to depress yields despite moderate levels of tan spot in some treatments (Fischer et al., 2002). Procházková et al. (2003) found that wheat yield was not affected significantly by continuous cropping and the high production ability of wheat in the long-term showed a high antiphytopathogenic potential of the soil studied.

Long-term studies are essential for obtaining information on the sustainability of agricultural systems (Berzsenyi et al., 2000), and probably the only way to determine whether various cropping systems will eventually sustain or degrade the productivity of the soil. The objective of this study was to evaluate wheat productivity in terms of grain yields in four soils of northern Greece and examine possible soil degradation (soil pH and organic matter content) after 25 years of continuous wheat cropping under conventional tillage practices.

2. Materials and methods

Wheat (*T. aestivum* L.), cv. Yecora, was grown continuously since 1980 in four different soil-textured fields (a sandy loam soil, a clay soil, a clay loam soil, and a sandy clay loam soil) of the Aristotle University Farm in northern Greece. Some characteristic properties of the soil of each experimental field, determined at the initiation of the experiment, are presented in Table 1. Mean annual rainfall at the area of the University Farm of Thessaloniki during the period of experimentation was 429 mm. Sixty nine percent of the total annual rainfall has been recorded from November to May with November and December to be the rainiest months of the year. Total monthly rainfall recorded near the experimental area for each growing season is shown in Table 2.

Conventional tillage practices including mouldboard plough, harrow disc, and cultivator (standard tillage practices for wheat production in the area) were used before sowing in each growing season. Sowing took place about mid November, which is the optimal time for wheat sowing in northern Greece. Wheat was sown in rows (spaced 16 cm apart) at a seeding rate of 150 kg ha^{-1}. Nitrogen (N) at 120 kg ha^{-1} and P_2O_5 at 60 kg ha^{-1} applied as ammonium sulfo-phosphate (20-10-0) were incorporated into the soil before disc harrowing each year. Weed control (including both grasses and broadleaf weeds) was achieved with appropriate herbicides registered for weed control in wheat such as diclofop-methyl, MCPA, chlorsulfuron, and clodinafop-propargyl. No irrigation was applied in any growing season. Each experimental field covered a 4-ha area. Wheat was harvested after mid-June and grain yield was adjusted to 13% grain moisture using a grain moisture meter (Wile-35, OT-tehdas Oy Co., Helsinki, Finland). Grain yield was determined by harvesting the total area of each experimental field and expressed

Table 1
Selected physicochemical characteristics of the four soils at the initiation of the experiment (0–30 cm depth)

	Soil 1	Soil 2	Soil 3	Soil 4
Sand (g kg^{-1})	585	61	357	528
Silt (g kg^{-1})	302	347	322	183
Clay (g kg^{-1})	113	592	321	289
Texture	Sandy loam	Clay	Clay loam	Sandy clay loam
pH (1:2 H_2O)	8.1	7.8	8.1	8.2
EC_{se} (dS m^{-1})	0.49	2.29	0.51	1.13
$CaCO_3$ (g kg^{-1})	39.5	28.2	127.2	52.7
Organic matter (g kg^{-1})	9.7	26.3	23.8	18.4
Total soil nitrogen (mg 100 g^{-1})	66	175	182	123
C/N ratio	7.1	8.6	7.6	8.6
Water holding capacity (%, w/w)	21.7	51.6	39.6	30.4
Permanent wilting point (%, w/w)	7.4	30.2	22.5	14.2
Available water (%)	14.3	21.4	17.1	16.2
Cation exchange capacity (me 100 g^{-1})	16.5	40.2	31.3	29.4