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The Influence of Different Fertilization Strategies on the Grain Yield of Field Peas (*Pisum sativum* L.) under Conventional and Conservation Tillage

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Abstract: Weather, tillage, and fertilization are the major factors affecting the grain yield of field peas (*Pisum sativum* L.). However, the impact of tillage and fertilization on yield is not well understood. Therefore, this experiment was initiated in 1999. In this manuscript, we report the data recorded during the period of 2011–2015 to quantify the impacts on yield. Field peas were planted in seedbeds prepared through conventional tillage (CT)—moldboard ploughing to the depth of 0.22 m; and minimum tillage (MT)—disking to the depth of 0.12 m. The crop received three fertilization treatments, including zero fertilization (control); nitrogen, phosphorus and potassium (NPK) mineral fertilization treatment; and NPK mineral fertilization plus the incorporation of pre-crop biomass. Five years' average data indicated the highest yield on fertilized treatments (2.85–2.98 t ha^{-1} vs. 2.66 t ha^{-1}) regardless of the tillage. When comparing the yield of fertilized treatments, the yield under CT (2.98 t ha^{-1}) was significantly higher than that of MT (2.85 t ha^{-1}). However, on non-fertilized treatments (less fertile plots), a higher yield was recorded under MT (2.71 t ha^{-1}) compared with CT (2.40 t ha^{-1}). Overall, the results of this study suggest that fertilizer application together with incorporation of the above-ground biomass of the previous crop may help sustain pea grain yield.

Keywords: conventional tillage; fertilization; field pea; minimum tillage; soil quality; yield

1. Introduction

Pulses or legumes have an irreplaceable function in sustainable crop production systems. The addition of field peas (*Pisum sativum* L.) in cereal-dominated crop rotations provides several long-term agronomic and ecological benefits and contributes to the sustainability of the system [1].

Field pea has a good pre-crop value for cereals and reduces the inputs of nitrogen (N) fertilizers due to its biologic fixation capacity [2]. The application of inorganic N fertilizer is not generally required for peas, but the early application of small quantities of N is recommended in soil with low N [3].

Phosphorus (P) is required for pea growth and biological nitrogen fixation. The application of 30–35 kg ha^{-1} P_2O_5 and 50 kg ha^{-1} K is sufficient to meet the crop requirements [4]. Peas also provide high-quality protein for human and animal nutrition [5]. In 2017, a total of 8.14 m ha of field peas was harvested globally with the top producers being Canada, Russia, China, India, and the United States [6]. Despite all the benefits, legume/pulse areas in central Europe have been declining for a long time. The lower yield and great dependence on environmental stress conditions (e.g., temperature extremes, precipitation patterns, and water stress conditions) are the main causes of farmers' lack of interest in legume/pulse cultivation, which has a negative impact on the sustainability aspects of cultivation systems. The yield instability in peas is affected by many biotic and abiotic factors [7].

Farmers are also concerned with the greater yield variability, poor competitiveness with weeds, and harvesting difficulties [8]. Despite this, the pea is well adapted to a wide range of climates, from semiarid to temperate maritime. In central and northern Europe, peas are generally sown in spring, whereas, in southern Europe they are mostly sown in mid-November. In northern Europe, autumn sowing is avoided due to the greater risk of frost damage during flowering. Grain legumes are currently underrepresented in European agriculture and produced on only 1.5% of the arable land compared with 14.5% on a worldwide basis [9]. The pea cropping intensity decreased over the last two decades in the central European region. For the promotion of field pea crop production, it is important to find strategies for improving pea yields, as it is an important crop for sustainable agricultural production systems.

Soil organic matter (SOM) acts as a binding agent for forming soil stable aggregates and improves the soil water holding capacity [10]. The input of SOM and its interaction with cultivation and mineral fertilization may improve the yield performance of field peas [11]. Studies on the production potential of pea genotypes, N balance, pre-crop effects [12], and the effect of different potassium fertilization rates on the yield and N uptake by field peas [13] are available. The influence of tillage systems on the productivity of field peas [14] is also well known. However, the impact of fertilization and tillage practices on pea yield and soil quality traits in central Europe, over multiple years has not been investigated and not understood.

For this study, we hypothesized that the grain yield of field peas could be improved by the incorporation of aboveground biomass under conventional (CT) or minimum (MT) tillage. The aim of this study was to comparatively assess the impact of mineral fertilizers and the incorporation of aboveground biomass of growing crops under conventional and minimum tillage on the yield of peas in the agroclimatic conditions of western Slovakia.

2. Materials and Methods

2.1. Site Description

Field experiments were conducted in 2011–2015 at the experimental station of the Slovak University of Agriculture in Nitra (Nitra, Slovakia: 48°19′ N and 18°09′ E; 175–200 m). The soil was classified as a Haplic Luvisol. The particle-size distribution (top 20 cm) was 360.4 g kg^{-1} of sand, 488.3 g kg^{-1} of silt, and 151.3 g kg^{-1} of clay. The bulk density was in the range of 1.5–1.68 g cm^{-3}. The soil carbon content was 1.29%, while the cation exchange capacity was 147.18 mmol kg^{-1}. On average, the soil pH was 6.96 (0–20 cm).

2.2. Experimental Treatments and Experimental Design

This experiment began in 1996 and lasted until 2015 without changing the arrangement of the treatment factors indicated below. However, in this manuscript, we report yields during the period of 2011–2015. The field pea was grown in a crop rotation sequence as follows: red clover

(*Trifolium pratense* L.); winter wheat (*Triticum aestivum* L.); field pea (*Pisum sativum* L.); maize (*Zea mays* L.); and spring barley (*Hordeum vulgare* L.).

Randomized block design, in factorial arrangement, with three replications was used. The two tillage systems were the conventional tillage CT—moldboard ploughing to the depth of 0.22 m, and minimum tillage MT—disking to the depth of 0.12 m. The three fertilization treatments were: (F1) zero fertilization as a control treatment; (F2) NPK mineral fertilization treatment; and (F3) NPK mineral fertilization and the incorporation of aboveground biomass of growing crops. In the fertilization treatments, mineral fertilizers in the amount of 30 kg ha P (as superphosphate) and 40 kg ha K (as potassium chloride) were applied by primary tillage in autumn and 30 kg of N in the form of calcium ammonium nitrate was applied before sowing.

Tillage was performed between October and the first week of November under appropriate soil moisture conditions. Prior to primary tillage treatments, the aboveground crop biomass was crushed or chopped using a Universal Straw Chopper TSN 200—Cabe. The semi-leafless pea cultivar Audit (Limagrain Europe S.A.) was sown on 16 March in 2011, 2012, and 2015, and 25 March in 2013 and 5 March in 2014 using a seed rate of 220 kg ha^{-1} with a 125 mm distance between rows and an 80 mm distance in the rows. To assess the legume crop response at the full ripening plant stage, the grain yield was determined for each sub-plot using a clean weight basis corrected to 14% moisture. The pea crop was harvested on 29 June 2011, 2 July 2012, 22 July 2013, 7 July 2014, and 6 July 2015 by a combine harvester (CLAAS, Serbia) with a 2 m cutter bar.

2.3. Chemical Analysis and Sample Preparation

Every spring during March–April, the soil was sampled to the depth of 0.20 m from five different locations of the treatments for water-stable aggregate (WSA) determination and with three replications for soil analysis of the fertilization and tillage treatments. The soil samples were mixed, air dried, and ground before the chemical analyses. The soil samples for WSA were also pre-sieved over sieves of a specific size. The size fraction of water stable aggregates (WSA) from 0.5–3 mm were further analyzed. In the size fraction of WSA organic carbon by Tyurin in the modification of Nikitin [15] and labile carbon content (C_L) according to Loginow et al. [16] were detected.

The soil carbon sequestration capacity (CSC) was quantified using the equation CSC = $\frac{C_{org}-C_L}{C_L}$, where C_{org} is the content of organic carbon (mg 100 g^{-1}) in a specific fraction of WSA, and C_L is the content of labile carbon (mg/100 g) in the same fraction of WSA. The contents of the available P, K, and Mg were determined using the Mehlich 3 extraction procedure [17]. The content of P was determined using the colorimetric method (Spectrophotometer Model: SP-830 PLUS Metertech Inc.), K by flame photometry (PFP7—Jenway), and Mg by atomic absorption spectrophotometry (AAS SensAA Dual by GBC Scientific Equation).

2.4. Statistical Analysis

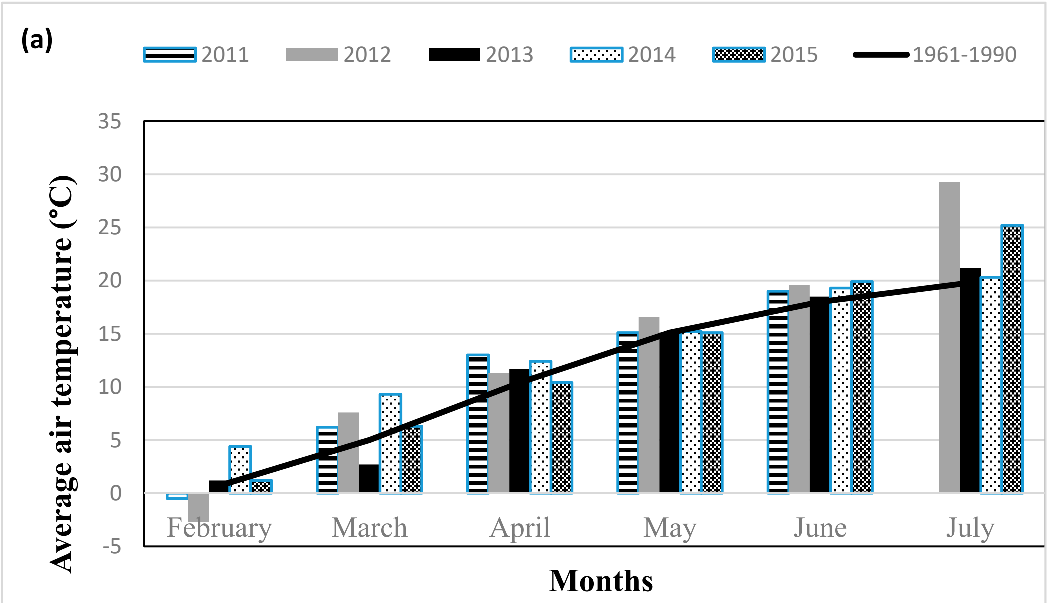
Prior to the statistical analysis, the data of the yield of the pea grains were checked for normal distribution using probability P-P plots and the Shapiro-Wilk test. An analysis of variance was used to analyze the impact of the tillage and fertilization treatments under different weather conditions of the evaluated years on the grain yield and water stable aggregates. The Fisher post-hoc test at the $p = 0.05$ level and Bartlett's, Cochran's, and Hartley's test for the equality of variance were performed using the Statistica 10 software (StatSoft Inc., Tulsa, OK, USA).

3. Results

3.1. Weather Conditions

The growing years of 2011–2015 created different temperature and humidity conditions, which were reflected in the yield and quality of peas. Predominantly higher temperature values compared to the standard climatological normal (1961–1990) were noted in March and April Figure 1), of which March

2012 was above normal (+2.6 °C) and March 2014 was extraordinary above normal (+4.3 °C). Only the temperature in March 2013 was below normal (−2.3 °C). In April, above normal temperatures were recorded in 2011 (+2.6 °C) and in 2014 (+2 °C). Except for the temperature in May 2012 (+1.5 °C), the May temperatures in the other four evaluated years were completely balanced in the range of 15.1–15.2 °C (Figure 1).



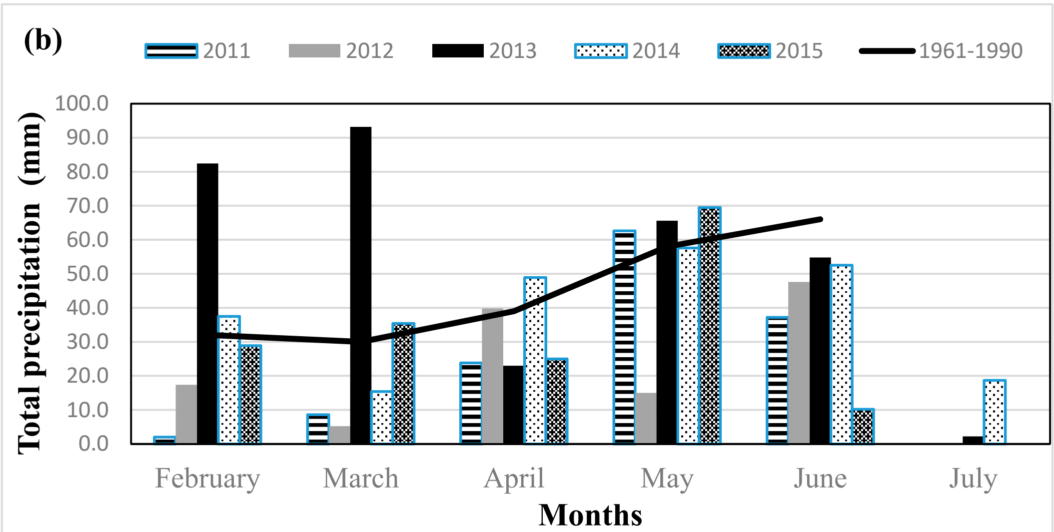


Figure 1. The average monthly air temperature (**a**) and total precipitation (**b**) during the crop growing season at the experimental site. The average July air temperatures were calculated for the date of the pea harvest. Source: Weather station of the Slovak University of Agriculture in Nitra, located on the experimental field.

June was generally characterized by a lack of precipitation compared to the standard climatological normal (1961–1990). The sum of the precipitation at the beginning of spring in 2011 and 2012 (March) was extraordinarily below normal but above normal in 2013. Only in May 2012, the precipitation was very below normal (−43 mm). The precipitation in April 2011, 2012, and 2013 was below normal with deficit of 14–16 mm [18].

3.2. Soil Conditions

During the evaluation period of 2011–2015, the fertilized plots were characterized by the average content of available P 90 mg kg^{-1}, K 283 mg kg^{-1}, and Mg 245 mg kg^{-1}. The soil carbon content of the fertilized plots varied in the range of 1.10% to 1.26% (Table 1). The content of organic carbon with zero treatments varied in the narrow interval of 1% to 1.08% as an average for both tillage treatments.

Table 1. Content of the available nutrients and soil carbon content in fertilized treatments.

Year	Treatment	Content of the Available Macronutrients in the Soil (mg kg^{-1})			C_{org} in %
		P	K	Mg	
2011	CT F2	87	225	286	1.12
	CT F3	82	250	298	1.15
	MT F2	79	275	299	1.15
	MT F3	80	265	298	1.21
2012	CT F2	80	225	214	1.12
	CT F3	75	275	232	1.21
	MT F2	79	250	215	1.23
	MT F3	82	275	214	1.26
2013	CT F2	113	280	198	1.16
	CT F3	120	260	237	1.17
	MT F2	88	275	225	1.23
	MT F3	100	290	220	1.21
2014	CT F2	78	300	226	1.13
	CT F3	83	320	225	1.10
	MT F2	100	340	269	1.14
	MT F3	103	320	261	1.15
2015	CT F2	108	340	226	1.01
	CT F3	95	300	225	1.12
	MT F2	78	280	269	1.15
	MT F3	100	320	261	1.12

CT—conventional tillage (moldboard ploughing); MT—minimum tillage (disking); F1—unfertilized plot; F2—NPK mineral fertilization treatment; F3—NPK mineral fertilization and precrop aboveground biomass incorporation; and C_{org}—soil organic carbon.

The effect of fertilization and tillage treatments on the carbon sequestration capacity of the selected size of water-stable macro-aggregates is documented in Table 2. Tillage had a significant effect on the size fraction of WS > 2 mm. The highest significant carbon sequestration capacity value was in the 2–3 mm size fraction under the MT tillage treatment. There was also a significantly higher level of WSA was in the size fraction of 2–3 mm of WTA under minimum tillage (disking). No significant differences in the carbon sequestration capacity were found between the fertilization treatments in any of the evaluated fractions.

Table 2. The carbon sequestration capacity of water-stable aggregates under the tillage and fertilization treatments.

WSA (mm)	Tillage Treatments		Fertilization Treatments		
	CT	MT	F1	F2	F3
0.5–1	5.54 ^{a}	5.47 ^{a}	5.26 ^{a}	5.98 ^{a}	5.45 ^{a}
1–2	5.98 ^{a}	5.92 ^{a}	5.90 ^{a}	5.25 ^{a}	5.69 ^{a}
2–3	6.03 ^{a}	6.34 ^{b}	6.00 ^{a}	5.13 ^{a}	6.04 ^{a}
C_{org} in WSA	1.20%	1.29%	1.24%	1.21%	1.28%

CT—conventional tillage (moldboard ploughing); MT—minimum tillage (disking); F1 unfertilized plot; F2—NPK mineral fertilization treatments; F3—NPK mineral fertilization and precrop aboveground biomass incorporation; and WSA water-stable macro-aggregate. Different letters refer to significant differences between columns. The treatment means were significantly different at $p < 0.05$.

3.3. Pea Grain Yield Factors

The year conditions and fertilization treatment explained the main part of the variation for the grain yield. The interaction of tillage, fertilization, and year conditions was another important source of variation (Table 3). The interaction of tillage or fertilization with the year conditions demonstrated a higher source of variation than the single effects of tillage or fertilization.

Table 3. Analysis of variance for the influence of tillage and fertilization on the grain yield of field peas over 2011–2015.

Source of Variation	Sum of Squares	Degree of Freedom	Mean Squares	F-Ratio	*p*-Value
Tillage (T)	0.080	1	0.08	7.82	0.013
Fertilization (F)	1.585	2	0.79	77.72	0.000
Year (Y)	45.013	4	11.25	1103.34	0.000
T × F	0.306	2	0.15	15.01	0.000
T × Y	2.137	4	0.53	52.38	0.000
F × Y	2.454	8	0.31	30.07	0.000
T × F × Y	2.877	8	0.36	35.26	0.000

The grain yield varied between years and fertilization treatments. During the trial period, the average yield of peas was 2.83 t ha^{-1}. In 2012 and 2013, less suitable growing conditions with an average yield of 1.93–2.09 t ha^{-1} were recorded (Table 4). In the driest year, 2012, a significantly higher pea seed yield was found on fertilization treatments under CT without a significant difference between the fertilization levels (CTF2, CTF3: 2.30 t ha^{-1}, 2.14 t ha^{-1}) compared to the pea yield at plots under minimum tillage (1.57 t ha^{-1}, 1.76, t ha^{-1}).

Table 4. Influence of tillage and fertilization on the grain yield of field peas during 2011–2015.

Years	No Fertilizer (F1)		NPK Mineral Fertilizers (F2)		NPK Mineral Fertilization + Pre-Crop Aboveground Biomass Incorporation (F3)		Mean (Years)
	CT	MT	CT	MT	CT	MT	
2011	3.00 ^{f}	3.12 ^{f,g}	3.13 $^{f–h}$	3.38 ^{j}	3.56 ^{k}	3.39 ^{j,k}	3.26C
2012	1.85 ^{b,c}	1.94 ^{c}	2.30 ^{d}	1.57 ^{a}	2.14 ^{d}	1.76 ^{b}	1.93A
2013	1.44 ^{a}	1.87 ^{bc}	1.76 ^{b}	2.56 ^{e}	2.72 ^{e}	2.21 ^{d}	2.09A
2014	3.30 $^{h–j}$	3.16 $^{f–i}$	3.06 ^{f,g}	3.18 $^{g–i}$	2.56 ^{e}	3.30 $^{h–j}$	3.09B
2015	3.47 ^{j,k}	3.44 ^{j,k}	4.2 ^{m}	3.33 ^{i,j}	4.4 ^{n}	3.78 ^{l}	3.77E
Means (Fertilizer)	2.66A		2.85B		2.98C		

CT—conventional tillage (moldboard ploughing); MT—minimum tillage (disking). Different letters refer to significant differences between treatments (small letter) and fertilization and year respectively (capital letter).

In 2015, agro-environmental conditions enabled the higher expression of the pea yield potential at the average level of 3.77 t ha^{-1}. In this year, the yield of pea seeds on plots without any fertilization was 3.47 t ha^{-1} and 3.44 t ha^{-1} under both tillage treatments (CT and MT). A significant increase in the pea yield compared to the unfertilized plots was recorded for both fertilization treatments in combination with moldboard ploughing (4.2–4.4 t ha^{-1}), with highest significant seed yield on the treatments with combined fertilization of industrial fertilizers and pre-crop biomass incorporation (CTF3).

On average over 5 years, both fertilization treatments achieved significantly higher yields compared to the unfertilized control by 7% to 12% (Table 4). Field peas grown on plots with CT and MT had a similar yield expressed in terms of the 5 -year average of grain yield per hectare (2.86 t ha^{-1} and 2.80 t ha^{-1}), but the yield of peas was more varied by the interaction of tillage and the year conditions (Figure 2).

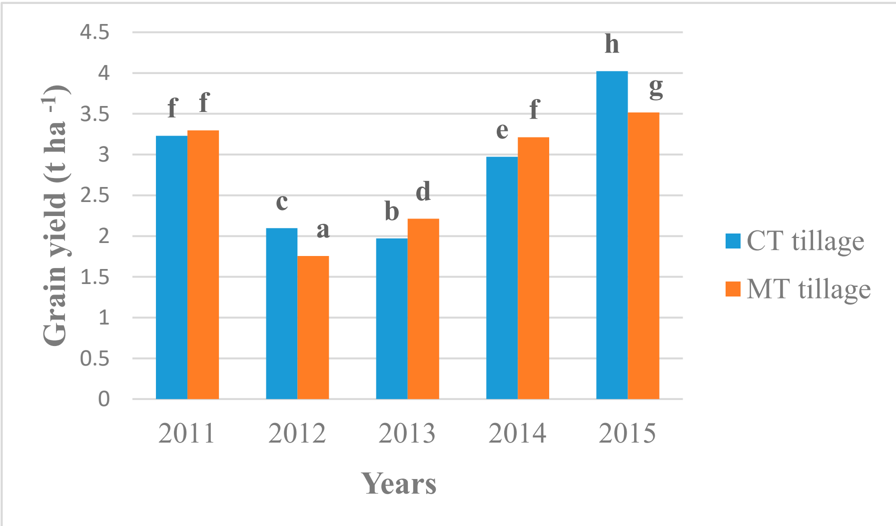


Figure 2. The field pea grain yield under different tillage practices during 2011–2015. CT—conventional tillage (moldboard ploughing); MT—minimum tillage (disking). Bars marked with different letters are significantly different at $p < 0.05$.

In the least fertile growing seasons of the years 2012 and 2013, the yield of pea grain was below 2.21 t ha^{-1} under both tillage treatments (Figure 2). The pea grain yield under different tillage practices indicates the higher magnitude of yield between tillage treatments in the most fertile year of 2015 in favor of CT in comparison to MT. Overall, the lowest yield was achieved under MT in the driest growing conditions of the year 2012. On the other hand, we recorded a higher yield on plots under MT in 2013 and 2014. In 2011, the effect of tillage cultivation did not affect the pea yield. Only the ploughing factor itself, did not have a uniform impact like fertilization (see below).

The average yield of field peas among fertilization treatments varied from 1.65 to 2.46 t ha^{-1} during 2012–2013. In more favorable growing conditions of the years 2011, 2014, and 2015, the significantly higher yield in range of 2.93 to 4.09 t ha^{-1} was noted (Figure 3).

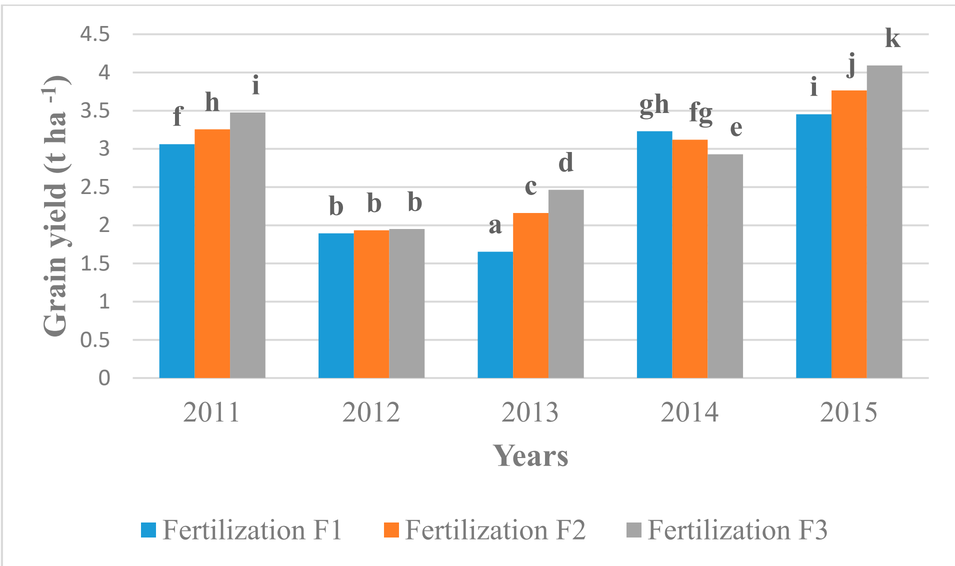


Figure 3. The yield of field pea grains under different fertilization treatments during 2011–2015. F1—unfertilized plot; F2—NPK mineral fertilization treatment; F3—NPK mineral fertilization and precrop aboveground biomass incorporation. Bars marked with different letters are significantly different at $p < 0.05$.

In the observed period of 2011–2015, the pea harvest was significantly influenced by fertilization in four growing seasons. In the dry weather conditions of the year 2012, an average yield of 1.93 t ha^{-1} was noted without any observed effect of fertilization. In 2011, 2013, and 2015, the pea seed yield increased significantly according to the increasing nutrient inputs F1 < F2 < F3. The growing year 2014 went beyond this trend because the fertilized treatments did not exceed the yield at the unfertilized control.

When looking for the best combination of fertilization management and tillage practices, it is advisable to evaluate the unfertilized control separately (Figure 4).

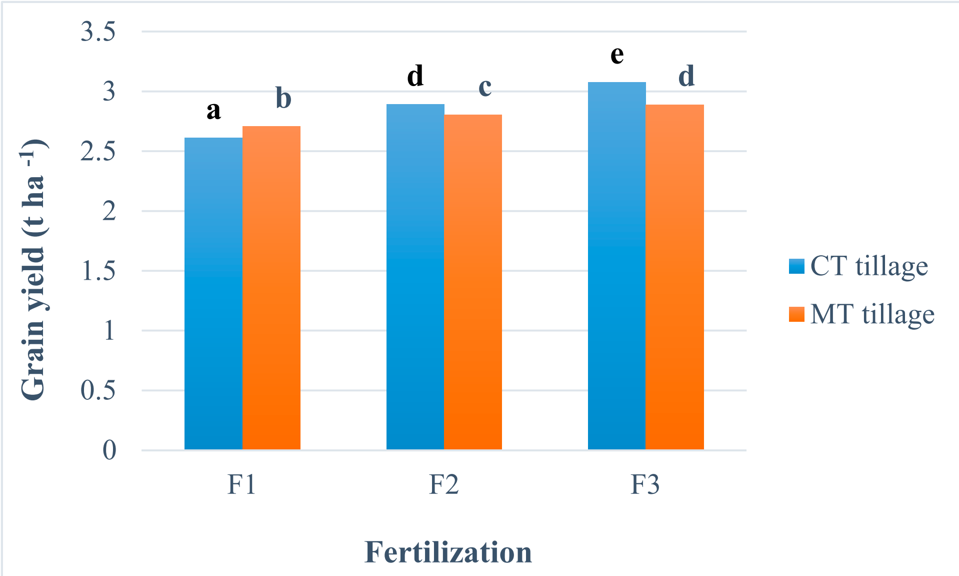


Figure 4. The yield of field pea grains under different tillage and fertilization management during 2011–2015. Vertical bars denote 0.95 confidence intervals; CT—conventional tillage (moldboard ploughing); MT—minimum tillage (disking); F1—unfertilized plot; F2—NPK mineral fertilization treatment; F3—NPK mineral fertilization and precrop aboveground biomass incorporation; Different letters refer to significant differences between treatments.

The average data of the evaluated treatments significantly indicates the highest yield on fertilized plots (F2 and F3) regardless of the tillage methods. When comparing the yield on fertilized plots, the yield under conventional tillage (F2, F3) was significantly higher with comparison to MT. As opposed to that on non-fertilized treatments, there were significantly higher yields under MT. An increasing pattern of seed yield (F1 < F2 < F3) was found on plots under CT with grain yields in the large range of 2.61–3.08 t ha^{-1}. A similar pattern was also noted under MT.

4. Discussion

In central Europe, field peas are typically grown in non-irrigated fields. High temperatures combined with a lack of precipitation mainly in coincidences with the period of grain yield determination was a significant factor of the growing season determining the grain yield of peas. According to our results, the minimum precipitation in May 2012 (15 mm) including 40-day periods without precipitation from 5 May to 14 June contributed to the lowest pea seed yield (1.93 t ha^{-1}) on average for all treatments and years.

March 2013 was one of the coldest months in our climatological records, and high precipitation delayed the crop sowing to 25 March. Research demonstrated that the precipitation status in May, during the growing stage of flowering and development of seeds, is decisive for the yield of peas grown in non-irrigated fields [19]. Similarly, Gantner et al. [20] showed that precipitation from February to May had the highest positive correlation with the average location yields. Due to the sowing delay, the canopy of peas reached the zone of higher June and July temperatures accompanied by dry conditions in the period of development of fruits, which had a negative effect on the yield formation.

Similarly, Payne et al. [21] indicated that the sum of the maximum daily temperatures above 25.6 °C during the reproductive phases of the crop had a negative effect on the yield. The critical period of the grain yield determination is useful for maximizing the grain yield via a proper management strategy. Considering a bottom line of a 10% reduction in grain yield, Sandańa and Calderini [22] established the critical periods for grain determination between 10 days before R1 and 50 and 40 days after R1. This period, according to Knott [23], corresponds to the flower bud development and seed-set stages in peas. Several other cereals and legume grain crops are also known to be sensitive to high temperature stress during the critical stages of floral bud development and seed-set [24–26]. On the other hand, a lack of precipitation in June did not have an important influence on the field pea yield. In 2015, only 10.2 mm of precipitation occurred in June, but field pea reached the highest significant yield (3.77 t ha^{-1}) of the whole evaluated period.

The yield stability of field grain growing in rainfed field conditions and increasing production costs are the main problems of the decreasing crop area in central Europe [14]. Whether farmers choose to grow more legumes will depend on the development of supply chains as well as technical improvements of grain legume production, such as management development to improve the yield stability [9]. Although year conditions explain yield variability, there is still a need to examine if other agrotechnical factors can contribute to higher yields of field peas. Soil cultivation and fertilization is a fundamental agronomic practice directly affecting the soil environment for growing crops.

Water-stable macro-aggregates are the most valuable part of the ploughing layer. Such an aggregation process provides physical protection to SOM by isolating it from decomposers [27], thus, preventing the decay of soil organic carbon. Therefore, the evaluation of the ability of carbon sequestration under CT and MT and different fertilization treatments may be one of the benefits of suitable tillage and fertilization management of peas. The size fraction from 0.5 mm to 3 mm included the most agronomically valuable macro-aggregates (WSA ma 0.5–3 mm). Researchers determined that reduced tillage of the soil positively influenced both the WSA and the yield of the crops grown [28]. The highest value of the carbon sequestration capacity was in the 2–3 mm size fraction of water-stable macro-aggregates (WSA_{ma}) under MT tillage. The range of the organic carbon content was in a narrow interval.

The pea reaction to various tillage conditions allows researchers to find optimal methods to reduce the tillage and conservation tillage [29]. Nitrogen fertilizer is not generally required; however, starter N applied early, prior to the onset of N fixation, was recommended for field pea production when soils are low in N [3]. Under these conditions in central Europe, the addition of 40 kg ha^{-1} of N with mineral fertilizer is recommended to provide N nutrition of the pea plant until nodulation becomes fully effective [30]. A substantial effect of N nutrition, assessed by the N nutrition index on the grain number, was observed [19].

The positive effect of P fertilization was reported by many studies [31,32]. Relatively small doses of mineral fertilization and mineral fertilization combined with the incorporation of pre crop biomass significantly increased the yield of grain peas by 130–320 kg ha^{-1} compared to the unfertilized control. In three of the five evaluated years, the trend (F1 < F2 < F3) of the impact of the evaluated fertilization treatments on the yield of peas was confirmed. The applied rates of N, P, and K were designed with regard to lower inputs and low environmental load, which reduced the use of the full fertilization potential in relation to the crop.

One of the most limiting nutrients for field peas is P because this legume crop requires significant inputs for nodule formation. Therefore, the P use efficiency should be considered important for sustainable agriculture [6], where one of the goals is decreasing the reliance on fertilizers and maximizing productivity. The response of the seed yield to P application is related to the content of extractable P in the soil. Karamanos et al. [31] reported a significant increase in the yield of peas as response to 19.5 kg ha^{-1} P application on soils with a lower content of extractable P. There was no significant yield increase in the trials that contained greater than 10 mg kg^{-1} extractable P in the soil.

Similarly, in our field trial, a good P supply was recorded during all periods of the field trial in a range of 75–88 mg kg^{-1} dry soil. Symanowicz et al. [13] reported the highest pea yield on the plots at a dose of 124 kg ha^{-1} K on the soil with a low K and high soil P supply. Such an influence was not recorded in the study by Bujak and Frant [33], were K was applied at a rate of 66–100 kg ha^{-1} on soil with high content of available K. In our experiments, there was a good soil supply of K in the range of 250–320 mg kg^{-1} of soil during the observed period.

Field peas grown on fertile soils are not very dependent on N doses except for during the initial stage of development. In agroclimatic conditions in central Europe, the field pea N fixation ranged from 53 to 75 kg ha^{-1}, corresponding to 42% to 50% of the N [10]. Despite a good soil supply of P and K, the effect of fertilization on pea yields was significant. Despite the relatively low doses of industrial fertilizers, we found a yield increase of 188 kg ha^{-1} over the control on plots with the application of mineral fertilizers and 323 kg ha^{-1} over the control on plots with combined doses of mineral fertilizers and the incorporation of aboveground biomass. The positive effect of combined fertilization was well manifested in the most fertile year of 2015 in both tillage methods. In the case of treatments with the application of only industrial fertilizers, there was a significantly better treatment with CT in comparison with MT in the favorable year conditions of 2015.

The pea yield in both tillage practices (CT and MT) produced about the same yields in the narrow range of 2.85–2.98 t ha^{-1} during 2011–2015; however, the yield of peas significantly differed by the interaction of the tillage and year condition. The average 5-year data indicated that pea cultivation with minimal tillage was possible. On plots under minimum tillage, the pea yield was 190 kg higher on treatments with a long history of ploughing aboveground biomass (MTF3) compared to plots fertilized only with industrial fertilizers (MTF2). However, in general, conventional tillage is recommended for field peas and some legumes [34,35].

For a deeper analysis of the impact of tillage practices, we must understand the impact of tillage separately on fertilized and non-fertilized plots (Figure 4). Non-fertilized (less fertile) plots achieved significantly higher yield under MT practices. Conventional tillage created demonstrably better growing conditions for realizing the production potential of peas in the interaction with fertilization management (higher fertile). The highest pea yield was achieved on plots with mineral fertilization and plowed pre-crop aboveground biomass (CTF3).

When evaluating fertilization treatments, we found a non-significant difference in the interactions with CT and MT. However, the benefits of MT on water soluble aggregates improved the soil quality in longer-term conditions. In addition, the benefits of MT on economics due to the lower energy-use-associated benefits requires further key analysis to determine the full benefits of MT on the yield, soil health, and profitability of the system.

5. Conclusions

The five years averaged data of the evaluated treatments significantly indicated the highest yield of pea seeds on fertilized plots regardless of the tillage methods. When comparing the yield of both fertilized treatments, the yield under CT was significantly higher with comparison to MT. In contrast to the non-fertilized treatments, there were significantly higher yields under minimum tillage. The highest value of the carbon sequestration capacity was in the 2–3 mm size fraction of water-stable macro-aggregates (WSA_{ma}) under MT tillage. The larger benefits of MT on the soil quality and yield stability of peas requires further evaluation. We recommend fertilizing peas with small doses of mineral fertilizers with the incorporation of the above-ground biomass of the previous crop. These measures can contribute to crop stabilization and the sustainability of the cultivation system.

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