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Imene Kerbouai
National Institute of Agronomy, Tunis

Khaled Sassi
Institut national agronomique de Tunisie (INAT)

Hatem Cheikh M'hamed
National Institute of Agronomic Research of Tunisia

Jenfaoui Houda
National Institute of Agronomy, Tunis

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Article

Influence of Conservation Agriculture on Durum Wheat Grain, Dough Texture Profile and Pasta Quality in a Mediterranean Region

Imene Kerbouai [1,2,*], Dorra Sfayhi [3], Khaled Sassi [2], Hatem Cheikh M'hamed [4], Houda Jenfaoui [5], Jouhaina Riahi [6], Slim Arfaoui [7], Moncef Chouaibi [8,9] and Hanen Ben Ismail [1,10]

1 Department of Agri-Food Industries, National Institute of Agronomy of Tunisia, University of Carthage, Tunis 1082, Tunisia
2 Laboratory of Genetic and Cereal Breeding, LR14AGR01, National Institute of Agronomy of Tunisia, University of Carthage, Tunis 1082, Tunisia
3 Field Crop Laboratory, LR16INRAT02, National Institute of Agronomic Research of Tunisia, University of Carthage, Rue Hedi Karray, Ariana 2049, Tunisia
4 Agronomy Laboratory, National Institute of Agronomic Research of Tunis (INRAT), University of Carthage, Hedi Karray Street, Ariana 2049, Tunisia
5 Laboratory of Bioagressor and Integrated Management in Agriculture, LR14AG R02, National Institute of Agronomy of Tunisia, University of Carthage, Tunis 1082, Tunisia
6 Technical Center for Organic Agriculture, BP 54, Sousse 4042, Tunisia
7 National Institute for Field Crops (INGC), BP 120, Bousalem 8170, Tunisia
8 Bio-Preservation and Valorization of Agricultural Products UR13-AGR 02, High Institute of Food Industries, University of Carthage, 58 Alain Savary Street, Tunis 1003, Tunisia
9 Higher School of Food Industries, 58, Alain Savary Street, Elkhadra City 1003, Tunisia
10 Faculty of Mathematical, Physical and Natural Sciences of Tunis, LR11ES09, University Tunis El Manar, Tunis 2092, Tunisia
* Correspondence: imene.kerbouai@gmail.com

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Abstract: There is a growing interest in the Mediterranean regions to switch to conservation agriculture (CA) to address climate change and soil deterioration issues. The novelty of this study lies in the quality of the supply chain, from the raw material (durum wheat grain) to the ready-to-sell product (spaghetti), under long-term CA, and using two varieties over two years of study. This study aims to investigate the impact of two soil management systems (SM) (CA after 10/11 (since 2009–2010) years switching vs. conventional tillage (CT)) on grain quality, dough texture profile, and pasta quality of two Tunisian durum wheat varieties (Karim and Monastir) in a 2-year-long experiment (2019 and 2020). The results showed that the SM had a significant impact on the grain quality in both years in terms of protein content and wet gluten, which were, respectively, lower under CA (11.92% vs. 11.15% for protein content) and (18.75% vs. 17.68% for wet gluten) in the wet year. These parameters increased in the dry year but they were higher under CA (15.70% vs. 14.42 ± 0.94% for protein content) and (26.00% vs. 23.20% for wet gluten). These results have, in turn, affected the dough quality (springiness, chewiness, and cohesiveness) and pasta cooking time and decreased the pasta cooking loss and water absorption index. In terms of the variety (V) factor, "Karim" variety in the dry year had a higher protein content and better dough quality than "Monastir" variety, and it reduced the pasta cooking time. In addition, the pasta yellow index (b*) from grains grown under CA was always higher than those in the CT system (23.99 vs. 19.72% and 25.24 vs. 22.19% in 2019 and 2020, respectively). The interaction between SM and V was significant in both years only for the dough hardness and pasta b* parameters. In conclusion, long-term CA may be a crucial solution in the dry season to promote food quality and achieve sustainable agriculture goals.

Keywords: conservation agriculture; conventional tillage; durum wheat grain; dough texture profiles; pasta quality; soil management

1. Introduction

Durum wheat (*Triticum durum* Desf) is an important crop worldwide, and is used mainly for pasta manufacturing. In Tunisia, much like Mediterranean countries, durum wheat has an important place in heritage foods [1] and it is the main crop cereal cultivation [2], where the surface cultivated in 2021 was 1,106,000 ha (ONAGRI, Tunis, Tunisia, 2021). In addition, the consumption of durum wheat by Tunisians was 1.252 million tons, an increase of 1% compared to 2018 (ONAGRI, Tunis, Tunisia, 2021) [3]. However, intensive crop production has resulted in soil degradation, which is distinguished into two groups: (1) physical and chemical soil degradation and (2) soil components transported by water and wind erosion [4]. In addition to the increase in the negative impacts of climate change on farms [5], the production is decreasing [6]. Therefore, scientists have proposed a shift to a sustainable agriculture system to address these problems and find solutions [7]. For these reasons, CA emerged as an important technique to replace the tillage system; it is defined by a set of soil management practices composed by no-till, crop rotation diversity, and permanent soil cover [8,9]. The FAO considered CA as the ideal solution to achieve sustainable agriculture goals by meeting the global demand for future generations while protecting the soil and the environment [10].

Tunisia, much like all the Mediterranean countries, was experiencing soil degradation due to climate change and intensive tillage. To face these challenges, Tunisian projects began to implement no-till/direct seeding from 1970 to 1980, which was followed later by the implementation of all CA principles [11].

Many review papers have examined the advantages of CA on crop yields [12,13], agro-ecological resources [14], economic inputs, and soil quality [15]. In particular, several studies have highlighted the benefits of switching to CA on the physical, chemical, and microbiological quality of soil [16]. In fact, CA improves soil structure [17], where the no-tillage system with mulch cover increases infiltration and water storage [18]. Straw cover reduces water evaporation, which lowers the soil temperature [19]. Moreover, mulch cover under no-tillage enriches the soil organic matter and nutrients on the topsoil layer [20]. Furthermore, the combination of no-till with the intercropping of sorghum and soybean increases the density of earthworms [21]. Additionally, [22] found that the barley–pea intercropping system decreased the operator and resident exposure of pesticides.

Linking to the soil management systems, researchers are currently very interested in improving crop quality through the agricultural practices [23]. It is well known that the genotypic factor, climatic conditions, soil proprieties, agronomic practices, and post-harvest grain storage processes are the most important factors affecting grain quality [24].

Durum wheat is the main crop used for making pasta, which is widely consumed throughout the world. In 2021, the top three pasta-consuming countries were Italy (23.5 kg), Tunisia (17 kg), and Venezuela (15 kg) [25]. The popularity of pasta is related to its good nutritional, technological, and sensory properties, as well as its low cost [26]. It is well known that protein, gluten, and starch are recognized for their strong influences on dough texture profile [27] and pasta cooking quality [28].

Recently, interest in crop quality in CA has increased because of the changes that occur in the soil after switching to CA. In addition, nitrogen is the critical factor affecting protein in durum wheat [29]. Its availability in the soil through legume/cereal rotation and mulch degradation increased under CA compared to CT [20,30]. This availability of nitrogen in the soil favors its uptake by the roots developed in CA [31]. The nitrogen assimilated by the plant is used for the synthesis of amino acids, then proteins and gluten in the grain [32]. For instance, a three-year experiment in Poland on the effect of different tillage systems [33] revealed that the protein and wet gluten content of winter wheat grains was not affected by the tillage system but by the year factor. Furthermore, [34] found no difference in the protein content between no-till and other tillage systems after two years of passage, which is explained by the need for a long-term conversion of at least seven years of no-till [35] and the absence of crop rotation with legumes and soil cover.

To the author's knowledge, there is no available information on the influence of CA on the dough texture analysis and pasta quality. Our study aimed to investigate (i) the effect of long-term CA vs. CT on two Tunisian durum wheat varieties (Karim and Monastir) on grain quality, dough texture profile, and pasta quality; (ii) the effect of the interaction between the soil management factor and the variety factor on quality parameters; and (iii) an understanding of the data matrix between quality parameters and individuals using Biplot-PCA.

2. Materials and Methods

2.1. Site Description

A long-term experimental trial (10–11 years) was carried out at the National Institute of Field Crops (INGC) located in Boussalem (Jandouba, Tunisia, 36° 32′ 51.89″ N, 9° 0′40.73″ E). The study area is characterized by a sub-humid climate. Weather conditions were recorded by a weather station located 1 km from the site. The field soil is a clay–loam soil, and its characteristics at the top layer (0–30) before site establishment are presented in Table 1. During the two-year experiment, the soil organic matter was 13.4 g kg^{-1} (2019) and 18.9 g kg^{-1} (2020) under CA, and 10.9 g kg^{-1} (2019) and 11.3 g kg^{-1} (2020) under CT.

Table 1. Soil characteristics of the top layer before implementing the long-term field experiments.

Soil Characteristics		**Value**
Soil texture	Clay (g kg^{-1})	340
	Silt (g kg^{-1})	455.6
	Sand (g kg^{-1})	194.4
Soil chemicals	Soil organic matter (g kg^{-1})	6.3
	pH	7.49
	Nitrogen (g kg^{-1})	1.62
	Potassium (g kg^{-1})	1.06
	Phosphorus (mg kg^{-1})	64.38

2.2. Climatic Conditions

Figure 1 shows monthly averages of temperatures and cumulated rainfall of the site for two years of the experiment (2019 and 2020) compared to the old data (1990–2020). Total precipitation varied between the two years, increasing in 2019 compared to 2020 by approximately 57% during the durum cycle. However, precipitation in the old data increased by about 45.01% and 76.22% compared to 2019 and 2020, respectively. With the exception of March where precipitation was higher in 2019 (115.5 mm) than old data (97.5 mm) and 2020 (78.4 mm). In April, the precipitation was higher in 2020 (82.8 mm) than the old data (74.5 mm) and 2019 (36 mm). However, precipitation decreased by 96% and 91.41% in May 2020 compared to 2019 and the old data, respectively.

The average temperature from November to May was higher in 2020, followed by the old data, and then in 2019. In the first three months (November, December, and January), the average temperature was higher for the old data, followed by 2019 and 2020. However, the average temperature in February, April, and May was higher in 2020, followed by the old data and 2019. The first year can be considered a wet season (favorable for the cereal), while the second year can be considered a dry season.

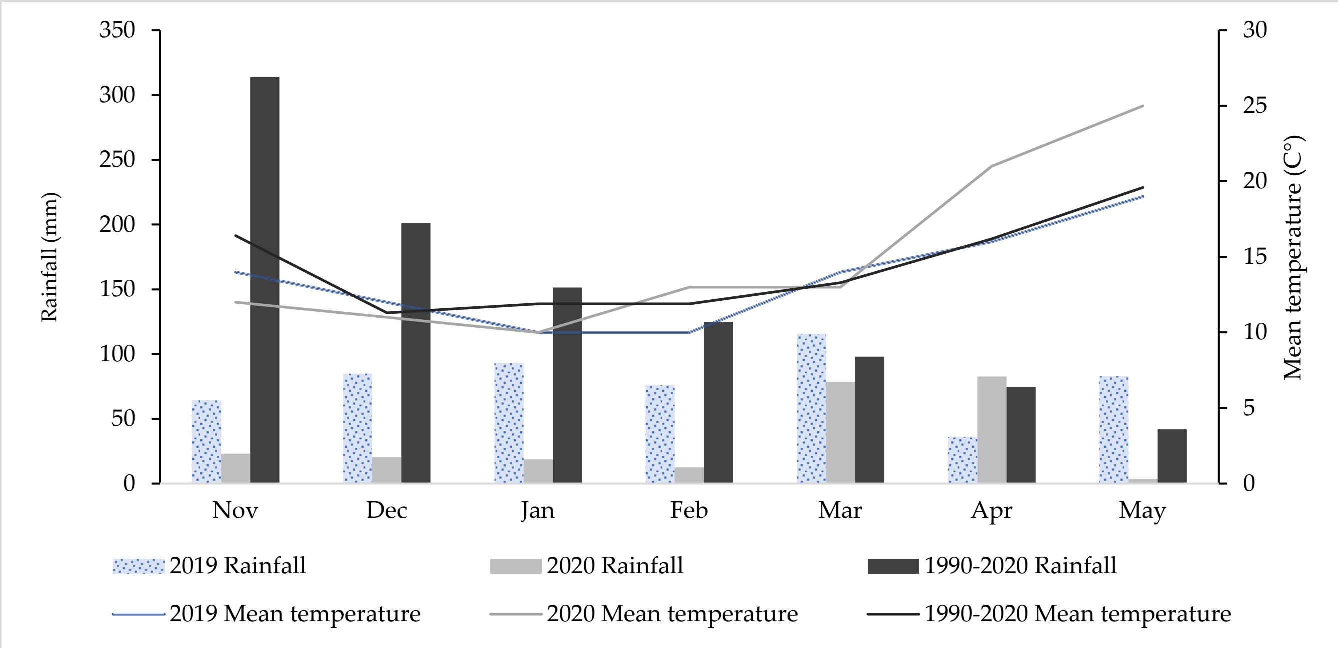

Figure 1. Monthly averages of temperatures (symbols) and cumulated rainfall (bars) at Bousalem—Tunisia during the two-cropping cycles of durum wheat 2019 and 2020 compared to 5-year data (2013–2018).

2.3. Experimental Design and Agronomic Management Systems

The present study was conducted in a successive two-year experiment (2019 and 2020). "Karim" and "Monastir" are modern Tunisian varieties introduced in 1980 and 2012, respectively. The "Karim" variety is considered the most cultivated in Tunisia, and the "Monastir" variety is known for its high resistance to diseases [36]. Both varieties were grown under two soil management systems, conservation agriculture (CA) and conventional tillage (CT), using a randomized complete block design with three replications (blocs where each bloc = 4280 m^2) and two factors: soil management system (first factor) and variety (second factor). Each plot size was 40 m × 53.5 m and the total area was 25,584 m^2.

The two soil management systems were compared and are described as follows: (1) CA, where the adoption has been ongoing since 2009–2010 and is based on no-tillage using a direct drill seeder (Semeato, Personale Drill 13 Model, Passo Fundo, RS, Brazil) on the residues of the previous crop. (2) CT, which consists of 3 soil tillage practices: starting with the turning of the soil to a depth of 25 cm using a disc harrow, followed by the disking of the soil, and finally, the softening of the seedbed. The cultivation of durum wheat was always preceded by faba beans (*Vicia faba* L. minor) in both systems. In both years, the sowing of durum wheat grain was realized in November with a seeding rate of 185 Kg ha^{-1} and 170 Kg ha^{-1} for the varieties "Karim" and "Monastir", respectively. In the case of the CA, Glyphosate 3 L ha^{-1} was dispersed in the field before seeding in both years. N-fertilization (ammonium nitrate (NH4NO3)) was used in three amendments (150,170 and 150 Kg ha^{-1}) in 2019 and (150 Kg ha^{-1} three times) in 2020 for both systems.

2.4. Grain Analysis and Semolina Milling

Grain vitrosity was determined using a Pohl farinator and the results were expressed as a percentage [34]. The protein content was calculated using the Kjeldahl method according to ISO 5983-1 [37], which multiplies the nitrogen content by 5.7. Wet gluten was determined by the hand wash method following the AACC 38-10.01 [38]. Semolina samples and dough preparation were obtained according to [39] with some modifications. Briefly, durum wheat grain was cleaned and conditioned at 16.5% moisture overnight. It was then ground using a CD2 CHOPIN technologies mill (Villeneuve-la-Garenne Cedex, France). The semolina yield was recorded and expressed in percentage.

2.5. Dough Texture Profile Analysis

Texture profile analysis of the dough (compression test) was performed using the TVT 6700 texture (Perten Instruments, Hägersten, Sweden). A total of 30 g of dough was placed in a cryogenic cylinder and compressed with an aluminum cylinder probe that was 75 mm in diameter. Two cycles up to 50% compression were applied at a speed of 10 mm/s, where the time between compressions was 12 s. The hardness, adhesiveness springiness, chewiness, and cohesiveness of the dough were calculated from the curve generated by the TVT texture analysis software according to the equations described by [40].

2.6. Pasta Processing and Quality Analysis

The dough was prepared by mixing semolina with tap water to obtain dough with a moisture content of 43–44%. Spaghetti-type pasta was extruded using a laboratory pasta machine (La Monferrina P3, Modena, Italy), and then dried (Pasta dryer la monferrina EC/NG 50, Italy) at a temperature of 50°C for 18 h [39,41]. The color of dried pasta was determined by the Konica Minolta spectrophotometer (CR-310, Tokyo). Optimum cooking time (OCT) and cooking loss (CL) of cooked pasta were determined by the AACC Approved Method 66–50 [38]. Briefly, in a laboratory beaker, dry pasta was cooked in distilled water and checked every 30 s. When the "*al dente*" dissipated, the OCT was recorded in minute. The beaker containing the pasta cooking water was dried in the oven at 105°C to a constant weight. The solid mass was weighed after drying, and the CL (%) was reported as a percentage of the starting mass. The cooked pasta was weighed, followed by oven-drying at 105°C until it reached a constant weight. Water absorption index (WAI) was calculated according to the following equation [42]:

$$WAI = \frac{(weight\ of\ cooked\ pasta\ -\ weight\ of\ pasta\ after\ drying)}{weight\ of\ pasta\ after\ drying}$$

2.7. Statistical Analysis

Two-way ANOVA (F-test) was used to assess the effect of the two factors (soil management and variety) and their interaction on the quality parameters. *p*-value at 0.05 and 0.01 was used to estimate significance between means using IBM SPSS software (version 22.0, IBM SPSS Inc., Chicago, IL, USA). Each year was treated separately. The R software [43] was used to perform a Biplot for principal component analysis (PCA). The normality (Shapiro–Wilk) and homogeneity (Bartlett) tests were verified before the ANOVA was tested. Three replications were performed for all studied parameters and the results were expressed on the basic dry weight.

3. Results

3.1. Grain Quality and Semolina Yield

The grain vitrosity was affected by soil management (SM) but only in the wet season (2019), where CA resulted in an increase in grain vitrosity by 16% compared to the CT (Table 2). However, the variety factor and its interaction with SM did not affect the grain vitrosity in both years.

The protein content in both seasons was affected by both factors, soil management (SM) and variety (V). It was lower under the CA system (11.92 ± 1.06 vs. 11.15 ± 1.15%) in the wet year (2019), but it was significantly higher (15.70 ± 0.98 vs. 14.42 ± 0.94%) in the dry year (2020) compared to CT. Additionally, the protein content of the "Karim" variety increased by 16% and 11% compared to the "Monastir" variety in 2019 and 2020, respectively. The protein content was insignificant ($p > 0.05$) when the soil management interacted with the variety factor in both years.

Table 2. Grain quality and semolina yield of two durum wheat varieties under two soil management systems (SM) grown over two cropping years.

	2019			**2020**		
	CA	**CT**	**Total Mean**	**CA**	**CT**	**Total Mean**
Grain vitrosity (%)						
Karim	91.33 ± 2.16	74.75 ± 2.82	83.04 ± 9.36	92.50 ± 2.05	93.75 ± 1.00	93.13 ± 1.59
Monastir	87.92 ± 1.26	75.17 ± 2.38	81.54 ± 7.19	92.33 ± 0.58	94.33 ± 0.76	93.33 ± 1.25
Total mean	89.63 ± 2.45	74.96 ± 2.34		92.42 ± 0.58	94.04 ± 0.86	
Soil management (SM)		(130.29) **			NS	
Variety (V)		NS			NS	
SMxV		NS			NS	
Protein content (%/dw)						
Karim	12.18 ± 0.09	12.88 ± 0.09	12.53 ± 0.39	16.59 ± 0.10	15.26 ± 0.35	15.93 ± 0.77
Monastir	10.11 ± 0.24	10.96 ±0.18	10.53 ±0.50	14.81 ±0.08	13.58 ±0.08	14.20 ±0.68
Total mean	11.15 ±1.15	11.92 ±1.06		15.70 ±0.98	14.42 ±0.94	
Soil management (SM)		(65.66) **			(139.01) **	
Variety (V)		(440.31) **			(252.79) **	
SMxV		NS			NS	
Wet gluten (%/dw)						
Karim	14.17 ± 0.71	22.40 ± 0.90	18.23 ± 4.57	24.60 ± 1.95	23.17 ± 2.10	23.88 ± 1.98
Monastir	21.20 ± 0.60	15.10 ± 0.50	18.15 ± 3.38	27.40 ± 1.77	23.23 ± 1.10	25.32 ± 2.64
Total mean	17.68 ± 3.90	18.75 ± 4.05		26.00 ± 2.26	23.20 ± 1.50	
Soil management (SM)		(7.10) *			(7.50) *	
Variety (V)		NS			NS	
SMxV		(320.45) **			NS	
Semolina yield (%)						
Karim	37.61 ± 0.25	36.68 ± 1.56	37.15 ± 1.13	37.29 ± 1.61	36.96 ± 0.31	37.13 ± 1.05
Monastir	40.65 ± 1.47	38.82 ± 0.92	39.74 ± 1.48	38.85 ± 0.51	38.01 ± 0.51	38.43 ± 0.65
Total mean	39.13 ± 1.91	37.75 ± 1.64		38.07 ± 1.37	37.49 ± 0.69	
Soil management (SM)		NS			NS	
Variety (V)		(14.53) **			(6.36) *	
SMxV		NS			NS	

** Significant at the 1% probability level. * Significant at the 5% level. NS: Non-significant. CA: Conservation agriculture. CT: Conventional tillage.

The wet gluten was significantly influenced by the SM system in both seasons. In the wet year, it was higher under CT (18.75 ± 4.05 vs. 17.68 ± 3.90%). However, in the dry year, it was higher under CA (26.00 ± 2.26 vs. 23.20 ± 1.50%). The wet gluten was insignificant between the "Karim" and "Monastir" varieties (Table 2). The interaction SMxV also affected this parameter ($p < 0.01$), but only in the wet year (2019). When the "Karim" variety was grown under CA, the wet gluten decreased by 37% compared to CT, which is contrary to the "Monastir" variety, where wet gluten increased by 29% under CA compared to CT.

The difference in the semolina yield was not significant between SM in both seasons. Yet, the variety factor was statistically affected, where it increased by 7% and 3% for "Monastir" more than the Karim variety in 2019 and 2020, respectively (Table 2). The SMxV interaction did not affect the semolina yield in both years.

3.2. Dough Texture Profile

During the two years, the dough hardness (DH) was significantly affected by the soil management (SM), the variety (V), and their interaction (Table 3). In particular, the DH of grains grown under the CA decreased more than those under the CT by about 17.23% in 2019 and 7% in 2020. The DH decreased by 13% (2019) and 9% (2020) more for the "Karim" variety than for the "Monastir" variety. When CA interacted with "Karim" and "Monastir" varieties, the DH of the grains was lower than in the CT, except for dough from the "Karim" variety grown in 2019, which was harder when it interacted with CA (575.67 ± 8.02 g) than CT (532.67 ± 10.26 g).

Table 3. Dough texture profile parameters of two durum wheat varieties under two soil management systems grown over two cropping years.

	2019			2020		
	CA	CT	Total Mean	CA	CT	Total Mean
Hardness (g)						
Karim	575.67 ± 8.02	532.67 ± 10.26	554.17 ± 24.95	557.33 ± 1.15	571.67 ± 13.01	564.50 ± 11.40
Monastir	502.33 ± 4.93	769.67 ± 8.39	636.00 ± 146.55	584.00 ± 15.10	655.00 ± 15.00	619.50 ± 41.15
Total mean	539.00 ± 40.61	651.17 ± 130.08		570.67 ± 17.47	613.33 ± 47.34	
Soil management (SM)		(571.16) **			(35.03) **	
Variety (V)		(304.01) **			(58.21) **	
SMxV		(1093.02) **			(15.45) **	
Adhesiveness (g.s^{-1})						
Karim	−1264.66 ± 69.53	−1137.27 ± 7.23	−1200.96 ± 82.60	−2705.71 ± 228.94	−1139.86 ± 30.10	−1922.79 ± 870.00
Monastir	−711.99 ± 18.38	−721.57 ± 45.88	−716.78 ± 31.70	−1079.09 ± 5.27	−1545.24 ± 80.50	−1312.16 ± 260.37
Total mean	−988.32 ± 306.11	−929.42 ± 229.57		−1892.40 ± 902.63	−1342.55 ± 228.59	
Soil management (SM)		(5.68) *			(60.64) **	
Variety (V)		(383.82) **			(74.78) **	
SMxV		NS			(207.04) **	
Springiness						
Karim	0.34 ± 0.05	0.40 ± 0.02	0.37 ± 0.05	0.84 ± 0.01	0.35 ± 0.05	0.60 ± 0.27
Monastir	0.21 ± 0.01	0.24 ± 0.03	0.23 ± 0.02	0.33 ± 0.06	0.33 ± 0.06	0.33 ± 0.06
Total mean	0.28 ± 0.07	0.32 ± 0.09		0.59 ± 0.29	0.34 ± 0.05	
Soil management (SM)		(7.52) *			(68.38) **	
Variety (V)		(78.03) **			(84.08) **	
SMxV		NS			(68.38) **	
Chewiness (g)						
Karim	72.83 ± 17.72	85.95 ± 4.74	79.39 ± 13.65	297.64 ± 14.20	76.90 ± 12.28	187.27 ± 121.49
Monastir	31.90 ± 4.30	53.45 ± 6.05	42.67 ± 12.70	69.51 ± 16.56	77.88 ± 16.94	73.70 ± 15.67
Total mean	52.36 ± 25.21	69.70 ± 18.46		183.57 ± 125.72	77.39 ± 13.24	
Soil management (SM)		(9.21) *			(148.12) **	
Variety (V)		(41.32) **			(169.46) **	
SMxV		NS			(172.42) **	
Cohesiveness						
Karim	0.37 ± 0.06	0.40 ± 0.01	0.39 ± 0.04	0.63 ± 0.03	0.38 ± 0.02	0.51 ± 0.14
Monastir	0.30 ± 0.02	0.29 ± 0.01	0.30 ± 0.02	0.36 ± 0.03	0.36 ± 0.02	0.36 ± 0.02
Total mean	0.34 ± 0.06	0.35 ± 0.06		0.50 ± 0.15	0.37 ± 0.02	
Soil management (SM)		NS			(77.01) **	
Variety (V)		(23.45) **			(98.61) **	
SMxV		NS			(77.01) **	

** Significant at the 1% probability level. * Significant at the 5% level. NS: Non-significant. CA: Conservation agriculture. CT: Conventional tillage.

Table 3 shows that the SM and V influenced the dough adhesiveness. The CA indicated higher values than the CT system (−988.32 ± 306.11 vs. −929.42 ± 229.57 g.s^{-1} in 2019 and −1892.40 ± 902.63 vs. −1342.55 ± 228.59 g.s^{-1} in 2020). The dough from the "Karim" variety was more adhesive (40.31% in 2019 and 38% in 2020) than that from the "Monastir" variety. The interaction SMxV affected the dough adhesiveness only in the dry year (2020), where the CA and "Karim" variety interaction was higher than the CT and "Karim" interaction (−2705.71 ± 228.94 vs. −1139.86 ± 30.10 g.s^{-1}); yet, the interaction of CA with the "Monastir" variety was lower than the interaction of CT with the "Monastir" variety (−1079.09 ± 5.27 vs. −1545.24 ± 80.50 g.s^{-1}).

The SM and V influenced the dough springiness (DS) and chewiness (DCH). Under CA plots, they decreased in the wet season (2019) (12.5% (DS) and 25% (DCH)), but they increased in the dry season (2020) (42.3% (DS) and 58% (DCH)) under CA than in CT. Doughs from the "Karim" variety showed more DS (38% in 2019 and 45% in 2020) and DCH (46% in 2019 and 61% in 2020) than those from the "Monastir" variety (Table 3). The SMxV interaction was significant for both parameters ($p < 0.01$) but only in 2020. The "Karim" variety grown under the CA system revealed more springiness (58%) and chewiness (74%) than that under CT. While in the case of "Monastir", both varieties were roughly similar for DS and decreased when the "Karim" variety was grown under the CA for DCH (11%) than "Monastir" (Table 3).

Concerning dough cohesiveness, the soil management affected it only in the dry year, where it was increased by about 26% under CA rather than CT. The variety factor affected the dough cohesiveness, where the "Karim" variety resulted in a higher value than the "Monastir" variety; 0.39 ± 0.04 vs. 0.30 ± 0.02 and 0.51 ± 0.14 vs. 0.36 ± 0.02 in 2019 and 2020, respectively. The interaction SMxV also affected the cohesiveness in the dry year only ($p < 0.01$), where the cohesiveness of the "Karim" variety was higher when it was grown under CA than CT (0.63 ± 0.03 vs. 0.38 ± 0.02) while, the dough cohesiveness for "Monastir" was roughly similar in both years.

3.3. Pasta Quality

Table 4 shows that the soil management (SM), the variety (V), and their interaction impacted the pasta yellow index b*. Yellowness increased in the pasta made from wheat grains grown under CA rather than in CT (18% (2019) and 12% (2020)). The pasta yellowness was higher for the "Karim" variety (13%) in the wet year and the "Monastir" variety (10%) in the dry year. The interaction SMxV was significant in both seasons ($p < 0.01$) and ($p < 0.05$) in 2019 and 2020, respectively, where the yellowness of the pasta for both varieties was higher under CA than CT.

Table 4. Pasta quality of two durum wheat varieties under two soil management systems grown over two cropping years.

	2019			2020		
	CA	**CT**	**Total Mean**	**CA**	**CT**	**Total Mean**
Yellow Index (b*) (%)						
Karim	26.43 ± 1.00	20.29 ± 0.30	23.36 ± 3.43	24.78 ± 0.90	20.11 ± 0.14	22.45 ± 2.62
Monastir	21.54 ± 0.58	19.14 ± 0.23	20.34 ± 1.37	25.69 ± 0.32	24.26 ± 2.15	24.98 ± 1.58
Total mean	23.99 ± 2.78	19.72 ± 0.68		25.24 ± 0.78	22.19 ± 2.65	
Soil management (SM)		(148.35) **			(19.99) **	
Variety (V)		(74.23) **			(13.76) **	
SMxV		(28.38) **			(5.66) *	
Optimum cooking time (min)						
Karim	9.41 ± 0.20	9.87 ± 0.27	9.64 ± 0.33	8.21 ± 0.11	7.46 ± 0.08	7.83 ± 0.42
Monastir	9.03 ± 0.06	9.37 ± 0.02	9.20 ± 0.19	10.61 ± 0.33	9.88 ± 0.23	10.25 ± 0.47
Total mean	9.22 ± 0.25	9.62 ± 0.32		9.41 ± 1.34	8.67 ± 1.34	
Soil management (SM)		(16.08) **			(35.51) **	
Variety (V)		(19.17) **			(381.15) **	
SMxV		NS			NS	
Cooking loss (%)						
Karim	6.23 ± 0.87	4.60 ± 0.95	5.42 ± 1.20	5.60 ± 0.15	5.85 ± 0.41	5.73 ± 0.31
Monastir	6.23 ± 0.18	5.74 ± 0.78	5.99 ± 0.57	4.39 ± 0.11	5.55 ± 0.22	4.97 ± 0.65
Total mean	6.23 ± 0.56	5.17 ± 0.99		5.00 ± 0.67	5.70 ± 0.34	
Soil management (SM)		(5.85) *			(23.41) **	
Variety (V)		NS			(27.35) **	
SMxV		NS			(9,70) *	
Water absorption index						
Karim	2.38 ± 0.05	2.25 ± 0.11	2.32 ± 0.10	2.18 ± 0.04	2.50 ± 0.10	2.34 ± 0.19
Monastir	2.33 ± 0.05	2.05 ± 0.03	2.19 ± 0.15	2.18 ± 0.13	2.64 ± 0.15	2.41 ± 0.28
Total mean	2.35 ± 0.05	2.15 ± 0.13		2.18 ± 0.08	2.57 ± 0.14	
Soil management (SM)		(27.26) **			(35.88) **	
Variety (V)		(10.58) *			NS	
SMxV		NS			NS	

** Significant at the 1% probability level. * Significant at the 5% level. NS: Non-significant. CA: Conservation agriculture. CT: Conventional tillage.

The pasta optimal cooking time (OCT) was affected by SM and V (Table 4). It was higher for wheat grains grown under CT (9.62 ± 0.32 min) than CA (9.22 ± 0.25 min) and was also higher for the "Karim" variety (9.64 ± 0.33 min) than the "Monastir" variety (9.20 ± 0.19 min) in the wet year (2019). However, under CA plots in the dry year (2020), the pasta needed more cooking time than CT (9.41 ± 1.34 vs. 8.67 ± 1.34 min); the same tendency for the Monastir (10.25 ± 0.47 min) and the "Karim" variety (7.83 ± 0.42 min) was obtained. The interaction SMxV did not affect the pasta cooking time ($p > 0.05$) in both years.

Unlike the OCT, the pasta made from wheat and grown under CA resulted in a higher cooking loss (CL) (6.23 ± 0.56 vs. 5.17 ± 0.99%) and water absorption index (WAI) (2.35 ± 0.05 vs. 2.15 ± 0.13) than the pasta derived from the CT trial in the wet year (2019), but in the dry year, the CL and WAI decreased by about 12% and 18%, respectively, under the same SM than CT. Furthermore, the "Karim" variety showed more CL in the dry year (5.73 ± 0.31 vs. 4.97 ± 0.65%) and WAI in the wet year (2.34 ± 0.19 vs. 2.41 ± 0.28). Additionally, when CA interacted with "Karim" and "Monastir", the CL of pasta decreased by 4% and 21%, respectively, compared to when they interacted with CT (Table 4).

3.4. PCA Biplot

Figure 2 represent the PCA biplot for two cropping years. The total variability for both dimensions was 84.6% and 87.3% in 2019 and 2020, respectively. On one hand, a clear opposition was observed between the two soil management systems (horizontal) and the two varieties (vertical).

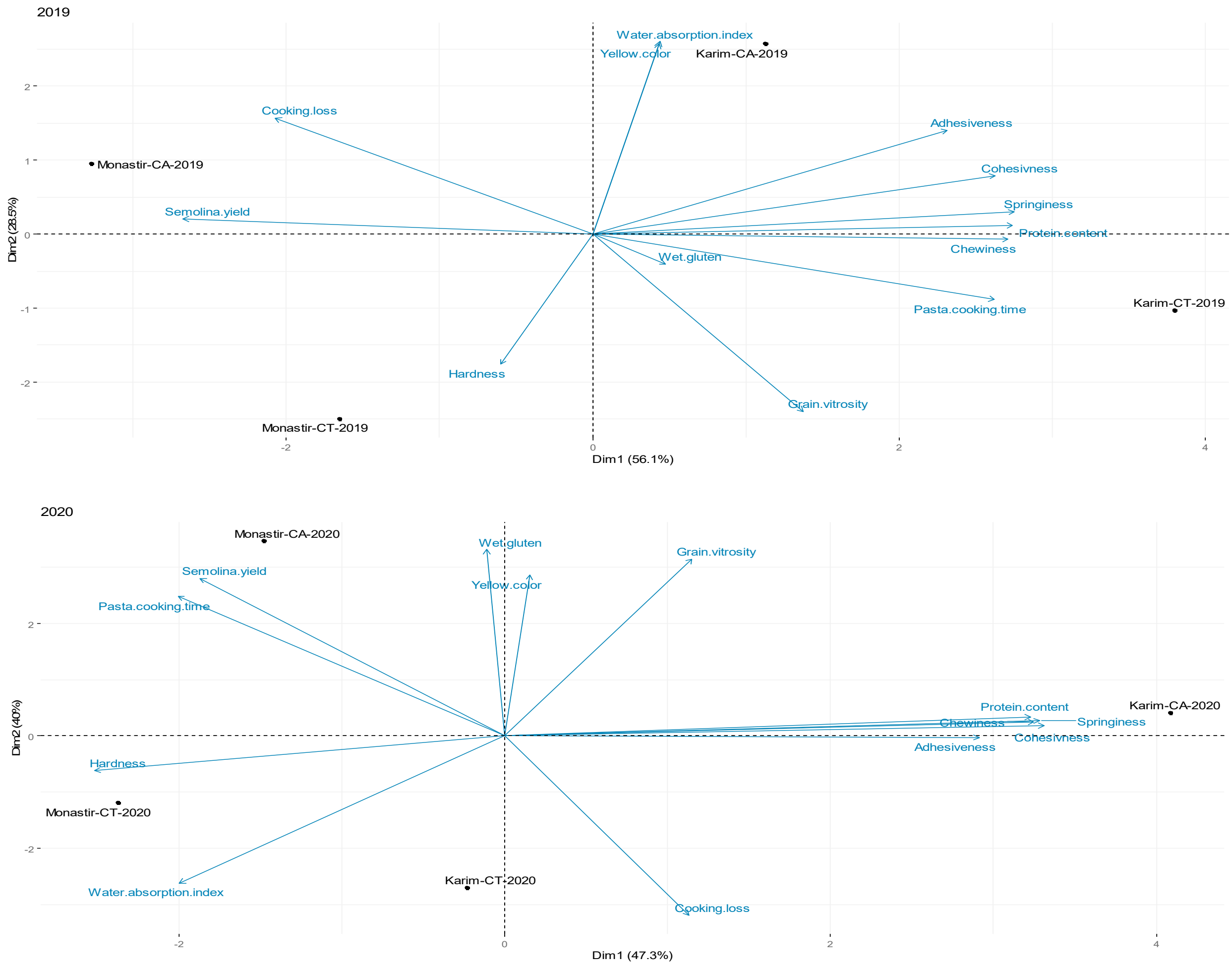

Figure 2. PCA for biplot of the quality parameters of "Monastir" and "Karim" varieties growing under CA and CT during 2019 and 2020.

In 2019, axis 1 is positively correlated with the protein content, springiness, cohesiveness, chewiness, adhesiveness, and pasta cooking time and negatively correlated with the semolina yield and pasta cooking loss (Table 5). While in 2020, the same axis is positively correlated with the protein content, springiness, cohesiveness, chewiness, and adhesiveness and negatively correlated with hardness. However, axis 2 is positively correlated with the yellow color and water absorption index and negatively correlated with grain vitrosity and hardness in 2019. In 2020, axis 2 is positively correlated positively with grain vitrosity, wet gluten, semolina yield, the yellow color, and pasta cooking time and negatively correlated with the cooking loss and water absorption index (Table 5).

Table 5. Biplot of principal component analysis based on the correlation matrix for quality parameters of durum wheat varieties grown under CA and CT during 2018 and 2019.

	2019		**2020**	
	Factor 1	**Factor 2**	**Factor 1**	**Factor 2**
Eigen values	7.3	3.7	6.1	5.2
Variance (%)	56.1	28.5	47.3	40
Cumulative %	56.1	84.6	47.3	87.3
	Variable correlations			
Grain vitrosity	0.496	−0.866	0.337	0.920
Protein content	0.990	0.042	0.945	0.099
Wet gluten	0.171	−0.148	−0.032	0.970
Semolina yield	−0.966	0.073	−0.547	0.821
Hardness	−0.217	−0.635	−0.737	−0.181
Springiness	0.994	0.108	0.962	0.079
Cohesiveness	0.950	0.285	0.969	0.055
Chewiness	0.979	−0.027	0.951	0.073
Adhesiveness	0.836	0.506	0.853	−0.007
Yellow color	0.158	0.929	0.046	0.836
Pasta cooking time	0.947	−0.320	−0.587	0.726
Pasta cooking loss	−0.748	0.567	0.331	−0.933
Water absorption index	0.159	0.939	−0.585	−0.766

In both years, the hardness was highly related to the "Monastir" variety under CT, while the combination of the same variety with CA showed a strong relationship with the semolina yield. On the other hand, the adhesiveness was strongly correlated to the "Karim" variety under CA. The yellowness indicator (b*) was always higher in the pasta that were made from the durum wheat that was grown under the CA compared to the other system, but it depended on the variety factor. In 2019, it was related to the "Karim" variety, but in 2020, it was related to the "Monastir" variety. The pasta cooking quality parameters depended on both the soil management systems and varieties. In 2019, the pasta cooking time (OCT) was related to the "Karim" variety under CT, the cooking loss of the "Monastir" variety under CA, and the water absorption index (WAI) of the "Karim" variety under CA. In 2020, the OCT was related to the combination "Monastir" variety under CA, the cooking loss was related to the "Karim" variety under CT, and WAI was related to the "Monastir" variety under CT.

4. Discussion

4.1. Grain Quality and Semolina Yield

The vitrosity of grains grown in the wet year (2019) (Figure 1) was better under CA than CT, which was in line with [34] under the no-tillage system compared to other tillage systems. The authors explain these results by the influence of higher rainfall conditions on soil nitrogen leaching under CT. On the other hand, [44] found that the soil cover reduces nitrogen loss in the drainage water.

According to [45], the protein content of durum wheat grown in the wet season (2019) was of low quality (< 13%). Whereas in the dry one (2020), it was considered high quality (>14%), except for the "Monastir" variety (CT), where it was considered medium quality (13–15%). In addition, the wet gluten of all the durum flours was classified as high quality (>14%), with higher values in the dry year than in the wet one. For soil management (SM), the CA system guaranteed high protein and wet gluten contents only in the dry year compared to the CT system. Inconsistent results were found in previous papers, where no statistical differences were found between tillage systems in the study of [46]. However, [47] found a low wet gluten and protein content of durum wheat grown under the no-tillage compared to the other tillage systems. The positive influence of CA in the dry year (2020) on these above parameters was probably due to the high temperature and low rainfall in 2020 (Figure 1) during the grain filling (milk stage), which are known to inhibit the formation of starch from sucrose and therefore increase the protein content in the grain, as highlighted by [48]. In the present study, the organic matter in the soil was higher under CA than CT and especially in 2020 than in 2019 (see materials and methods), which was due to the mulch cover degradation [20] and the influence of the intercropping system on the soil quality, as found by [49,50]. Soil under the CA system is characterized by high moisture content [51], as well as the density of the root system, which is more developed under no-tillage than CT [31]. All of the above parameters promote nitrogen uptake and assimilation by the plant under CA [52], which favors the formation of protein from nitrogen [29].

Moreover, the interaction between soil management and variety (SMxV) influenced the wet gluten in 2019, which can be explained by the influence of the interaction between the environment and genetic factors on wet gluten, as found by [53].

Similarly to this study, the yield from wheat grain was not significant between no-tillage and CT according to [54]. It was found that the semolina yield was majorly influenced by the genetic factor [55]. This can explain the impact of the variety factor in both seasons. Additionally, [56] found a positive correlation between the semolina yield (SY) and test weight (TW). The TW parameter for the same varieties (Karim and Monastir) was tested in our previous published study [57]. The Monastir variety in 2019 had the highest TW (82.33 ± 0.46 kg/hL), giving the highest SY (40.65 ± 1.47%) in the current study in 2019, which confirms this positive correlation.

4.2. Dough Texture Profile

The dough hardness is affected by the competition of gluten with fiber to water [58]. In 2019, the interaction SMxV indicated a strong negative correlation between wet gluten and dough hardness (Figure 2. 2019). The increase in dough hardness could be due to the low wet gluten. Regarding [59], adding fiber to the dough made it harder, thanks to the fiber's high water absorption rate and low water distribution in the gluten network. In particular, the higher dough hardness under CT was probably due to the low nitrogen level availability in the soil and lesser uptake by the plant under this system, which decreased the wet gluten content in semolina and resulted in a greater hardness of the dough.

A strong correlation was found between the protein content and adhesiveness (Figure 2). It was demonstrated that increasing the gliadin levels increases the adhesiveness of the dough [60]. Similarly, [61] reported that adding decreasing levels of fiber to flour increased the dough adhesiveness, which is likely due to the high water uptake by gliadin. The higher dough adhesiveness under CA in the current paper may be related to the high level of gliadin in durum wheat grain, which in turn, is linked to the higher nitrogen rate in the soil [62].

The high levels of dough's elasticity, cohesion, and chewiness under CA in the dry year (2020) were probably related to the high soil nitrogen content affecting the protein and gluten quality, whereby Figure 2 demonstrates a positive correlation between the protein content and these parameters. In the study conducted by [63], two common types of buckwheat: CBH (Common buckwheat hull) and CBB (Common buckwheat bran) were added to wheat flour. The dough's springiness and chewiness were higher in the dough added by CBB due to its higher protein content than CBH. The dough's elasticity varies because of many factors, namely, protein content, damaged starch, and water–starch bonding for hydrated grains [64]. A recent study showed that pistachio flour increased the dough's springiness and cohesiveness due to the pistachio protein; this may be due to the water availability within the developed gluten network [65].

Except for dough's hardness, all other textural parameters indicated higher values for "Karim" than "Monastir" variety, and this is due to the effect of genetic factors on the dough, as found by [66].

4.3. Pasta Quality

The yellow color is a desirable acceptance trait for pasta consumers. Many factors can influence it, namely, genetic factors, farm management, environmental conditions, and grain processing [67]. Regarding [68], the results did not show a significant difference in the semolina b* between the soil systems. The higher levels of yellowness were found in pasta made from durum wheat grown under CA in the current study were probably due to the change in the soil organic matter after a long-term transition (10/11 years), as discussed previously. Switching to the CA improves the accumulation of mineral elements such as potassium (K) [12]. K increases acetic thiokinase (ligases) activity. This enzyme is directly involved in the formation of acetoacetyl CoA, which promotes the biosynthesis of carotenoid precursors (isopentenyl diphosphate) [69].

The b* index of the two varieties changed according to the environment; this is called the cross-over interaction, and it can help farmers to select the best variety in a particular environment [70].

The high protein content and gluten network increased the cooking time of the pasta [71], which explains the lower cooking time of pasta made from wheat grown under CT in the first year (2019) and the highest cooking time for the pasta made from the wheat grown under CA in the dry year (2020), which is similar to the results of the current study regarding protein and wet gluten. The high protein and gluten network increase the cooking time by slowing down starch gelatinization and forming a solid network system with the starch [72]. The solid gluten network envelops the starch granules (gluten–starch system) to reduce their water absorption [73] for pasta made from the grown durum wheat over the dry year under CA. Additionally, it results in less swelling and fewer cooking losses [74], which could explain the lower water uptake and cooking loss under CA than under CT in the dry year (2020), which are due to the gluten network development.

Similarly, the variety factor affected the cooking quality of pasta. This is largely related to the difference in the composition of raw materials between varieties [75].

5. Conclusions

The results of a two-year experiment on two Tunisian durum wheat varieties have shown that long-term switching from CT to CA has an impact on the grain quality, dough texture profile, and pasta quality. In fact, the following conclusions may be made:

- The grain vitrosity was affected by SM only in the wet year, which increased under CA, while the protein content and wet gluten were affected by SM in both years, and the CA resulted in higher values in the dry year only.
- Dough hardness was always higher under CT, but dough adhesiveness, springiness, chewiness, and cohesiveness were higher under CA only in the dry year, which positively correlated with the protein content.
- The pasta yellowness was increased under CA rather than CT in both seasons. The pasta cooking time was higher under CA in the dry year thanks to the protein content and quality, while the cooking loss and water absorption index were lower in the same season.

- The "Karim" variety gave a high protein content, dough adhesiveness, springiness, chewiness, and cohesiveness, while the "Monastir" variety resulted in a higher semolina yield and dough hardness.
- Interaction soil management and variety were affected in both years, but only in terms of the pasta's yellowness and dough's hardness.

Due to the problems faced in agriculture in Tunisia, the application of conservation agriculture is necessary to protect the arable land from the impacts of climate change and soil deterioration through extensive tillage. The application of conservation agriculture can be a crucial solution, especially in areas with low rainfall. However, the adoption of CA in Tunisia also requires the use of a no-till drill (direct drill seeder) that is specifically designed for smallholders. In addition, strategies to minimize the amount of glyphosate in CA need to be developed.

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References

1. Lhomme, J.P.; Mougou, R.; Mansour, M. Potential impact of climate change on durum wheat cropping in Tunisia. *Clim. Change* **2009**, *96*, 549–564. [CrossRef]
2. Latiri, K.; Lhomme, J.P.; Annabi, M.; Setter, T.L. Wheat production in Tunisia: Progress, inter-annual variability and relation to rainfall. *Eur. J. Agron.* **2010**, *33*, 33–42. [CrossRef]
3. ONAGRI. Observatoire National de L'agriculture. 2021. Available online: http://www.onagri.nat.tn/uploads/lettre/LETTRE-1-2022-VERSION.F.pdf (accessed on 20 March 2023).
4. Kassam, A.H.; Basch, G.; Friedrich, T.; Shaxson, F.; Goddard, T.; Amado, T.; Crabtree, B.; Hongwen, L.; Mello, I.; Pisante, M.; et al. Sustainable soil management is more than what and how crops are grown. In *Principles of Soil Management in Agro-Ecosystems*, 1st ed.; Advances in Soil Science; Lal, R., Stewart, B.A., Eds.; CRC Press; Taylor & Francis Group: Boca Raton, FL, USA, 2013; Chapter 14; pp. 338–399.
5. Lal, R. Climate Change and Soil Degradation Mitigation by Sustainable Management of Soils and Other Natural Resources. *Agric. Res.* **2012**, *1*, 199–212. [CrossRef]
6. Anderson, W.K.; Impiglia, A. Management of dryland wheat. In *Bread Wheat*; FAO: Rome, Italy, 2002; ISBN 92-5-104809-6.
7. Lal, R. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science* **2004**, *304*, 1623–1627. [CrossRef] [PubMed]
8. Hobbs, P.R.; Sayre, K.; Gupta, R. The Role of Conservation Agriculture in Sustainable Agriculture. *Philos. Trans. R. Soc. B Biol. Sci.* **2008**, *363*, 543–555. [CrossRef] [PubMed]
9. Rinaldi, M.; Almeida, A.S.; Álvaro Fuentes, J.; Annabi, M.; Annicchiarico, P.; Castellini, M.; Cantero Martinez, C.; Cruz, M.G.; D'Alessandro, G.; Gitsopoulos, T.; et al. Open Questions and Research Needs in the Adoption of Conservation Agriculture in the Mediterranean Area. *Agronomy* **2022**, *12*, 1112. [CrossRef]
10. Derpsch, R. No-Tillage and Conservation Agriculture: A Progress Report. *No-Till Farming Syst.* **2008**, *3*, 7–39.
11. M'hamed, H.C.; Bahri, H.; Annabi, M.; Frija, A.; Idoudi, Z. Historical Review and Future Opportunities for Wider Scaling of Conservation Agriculture in Tunisia. In *Conservation Agriculture in Africa: Climate Smart Agricultural Development*; CABI: Wallingford, UK, 2022; pp. 137–150.
12. Sithole, N.J.; Magwaza, L.S.; Mafongoya, P.L. Conservation Agriculture and Its Impact on Soil Quality and Maize Yield: A South African Perspective. *Soil Tillage Res.* **2016**, *162*, 55–67. [CrossRef]
13. Shrestha, J.; Subedi, S.; Timsina, K.; Chaudhary, A.; Kandel, M.; Tripathi, S. Conservation agriculture as an approach towards sustainable crop production: A Review. *Farming Manag.* **2020**, *5*, 7–15.
14. Eze, S.; Dougill, A.J.; Banwart, S.A.; Hermans, T.D.G.; Ligowe, I.S.; Thierfelder, C. Impacts of Conservation Agriculture on Soil Structure and Hydraulic Properties of Malawian Agricultural Systems. *Soil Tillage Res.* **2020**, *201*, 104639. [CrossRef]
15. Ngwira, A.R.; Thierfelder, C.; Lambert, D.M. Conservation Agriculture Systems for Malawian Smallholder Farmers: Long-Term Effects on Crop Productivity, Profitability and Soil Quality. *Renew. Agric. Food Syst.* **2013**, *28*, 350–363. [CrossRef]

16. Parihar, C.M.; Yadav, M.R.; Jat, S.L.; Singh, A.K.; Kumar, B.; Pradhan, S.; Chakraborty, D.; Jat, M.L.; Jat, R.K.; Saharawat, Y.S.; et al. Long Term Effect of Conservation Agriculture in Maize Rotations on Total Organic Carbon, Physical and Biological Properties of a Sandy Loam Soil in North-Western Indo-Gangetic Plains. *Soil Tillage Res.* **2016**, *161*, 116–128. [CrossRef]
17. Azooz, R.H.; Arshad, M.A. Soil Infiltration and Hydraulic Conductivity under Long-Term No-Tillage and Conventional Tillage Systems. *Can. J. Soil Sci.* **1996**, *76*, 143–152. [CrossRef]
18. Verhulst, N.; Govaerts, B.; Verachtert, E.; Castellanos-Navarrete, A.; Mezzalama, M.; Wall, P.; Deckers, J.; Sayre, K.D. Conservation Agriculture, Improving Soil Quality for Sustainable Production Systems. In *Advances in Soil Science: Food Security and Soil Quality*, 1st ed.; Lal, R., Stewart, B.A., Eds.; CRC Press: Boca Raton, FL, USA, 2010; pp. 137–208.
19. Greb, B.W. Effect of Surface-Applied Wheat Straw on Soil Water Losses by Solar Distillation. *Soil Sci. Soc. Am. J.* **1966**, *30*, 786–788. [CrossRef]
20. Martínez, I.; Chervet, A.; Weisskopf, P.; Sturny, W.G.; Etana, A.; Stettler, M.; Forkman, J.; Keller, T. Two Decades of No-till in the Oberacker Long-Term Field Experiment: Part I. Crop Yield, Soil Organic Carbon and Nutrient Distribution in the Soil Profile. *Soil Tillage Res.* **2016**, *163*, 141–151. [CrossRef]
21. Obalum, S.E.; Obi, M.E. Physical Properties of a Sandy Loam Ultisol as Affected by Tillage-Mulch Management Practices and Cropping Systems. *Soil Tillage Res.* **2010**, *108*, 30–36. [CrossRef]
22. Zemmouri, B.; Lammoglia, S.-K.; Bouras, F.-Z.; Seghouani, M.; Rebouh, N.Y.; Latati, M. Modelling human health risks from pesticide use in innovative legume-cereal intercropping systems in Mediterranean conditions. *Ecotoxicol. Environ. Saf.* **2022**, *238*, 113590. [CrossRef]
23. Pandey, V.L.; Mahendra Dev, S.; Jayachandran, U. Impact of Agricultural Interventions on the Nutritional Status in South Asia: A Review. *Food Policy* **2016**, *62*, 28–40. [CrossRef]
24. López-Bellido, L.; López-Bellido, R.J.; Castillo, J.E.; López-Bellido, F.J. Effects of Long-Term Tillage, Crop Rotation and Nitrogen Fertilization on Bread-Making Quality of Hard Red Spring Wheat. *Field Crops Res.* **2001**, *72*, 197–210. [CrossRef]
25. IPO. International Pasta Organization. Available online: https://internationalpasta.org/pasta/ (accessed on 17 June 2022).
26. Bresciani, A.; Pagani, M.A.; Marti, A. Pasta-Making Process: A Narrative Review on the Relation between Process Variables and Pasta Quality. *Foods* **2022**, *11*, 256. [CrossRef]
27. Gao, X.; Tong, J.; Guo, L.; Yu, L.; Li, S.; Yang, B.; Wang, L.; Liu, Y.; Li, F.; Guo, J.; et al. Influence of Gluten and Starch Granules Interactions on Dough Mixing Properties in Wheat (*Triticum aestivum* L.). *Food Hydrocoll.* **2020**, *106*, 105885. [CrossRef]
28. Padalino, L.; Mastromatteo, M.; Lecce, L.; Spinelli, S.; Conte, A.; Del Nobile, M.A. Effect of Raw Material on Cooking Quality and Nutritional Composition of Durum Wheat Spaghetti. *Int. J. Food Sci. Nutr.* **2015**, *66*, 266–274. [CrossRef] [PubMed]
29. Troccoli, A.; Borrelli, G.M.; De Vita, P.; Fares, C.; Di Fonzo, N. Durum wheat quality: A multidisciplinary concept. *J. Cereal Sci.* **2000**, *32*, 99–113. [CrossRef]
30. Danga, B.O.; Ouma, J.P.; Wakindiki, I.I.; Bar-Tal, A. Legume—Wheat rotation effects on residual soil moisture, nitrogen and wheat yield in tropical regions. *Adv. Agron.* **2009**, *101*, 315–349. [CrossRef]
31. Osunbitan, J.A.; Oyedele, D.J.; Adekalu, K.O. Tillage Effects on Bulk Density, Hydraulic Conductivity and Strength of a Loamy Sand Soil in Southwestern Nigeria. *Soil Tillage Res.* **2005**, *82*, 57–64. [CrossRef]
32. Grahmann, K.; Verhulst, N.; Buerkert, A.; Ortiz-Monasterio, I.; Govaerts, B. Nitrogen use efficiency and optimization of nitrogen fertilization in conservation agriculture. *CAB Rev. Perspect. Agric. Veter. Sci. Nutr. Nat. Resour.* **2013**, *8*, 1–19. [CrossRef]
33. Woźniak, A.; Rachoń, L. Effect of Tillage Systems on the Yield and Quality of Winter Wheat Grain and Soil Properties. *Agriculture* **2020**, *10*, 405. [CrossRef]
34. Djouadi, K.; Mekliche, A.; Dahmani, S.; Ladjiar, N.I.; Abid, Y.; Silarbi, Z.; Hamadache, A.; Pisante, M. Durum Wheat Yield and Grain Quality in Early Transition from Conventional to Conservation Tillage in Semi-Arid Mediterranean Conditions. *Agriculture* **2021**, *11*, 711. [CrossRef]
35. Pagnani, G.; Galieni, A.; D'Egidio, S.; Visioli, G.; Stagnari, F.; Pisante, M. Effect of Soil Tillage and Crop Sequence on Grain Yield and Quality of Durum Wheat in Mediterranean Areas. *Agronomy* **2019**, *9*, 488. [CrossRef]
36. Abdedayem, W.; M'Barek, S.B.; Souissi, A.; Laribi, M.; Araar, C.; Kouki, H.; Fakhfakh, M.; Yahyaoui, A. Septoria tritici blotch disease progression and physiological traits variation in durum wheat variety mixtures. *J. New Sci.* **2021**, *80*, 4664–4674.
37. *ISO 5983–1:2005*; Animal Feeding Stuffs—Determination of Nitrogen Content and Calculation of Crude Protein Content—Part 1: Kjeldahl Method. International Organization for Standardization (Geneva, Switzerland). ISO: London, UK, 2005.
38. AACC International. *Approved Methods of Analysis*, 10th ed.; American Association of Cereal Chemists International: St. Paul, MN, USA, 2000.
39. Borrelli, G.M.; Troccoli, A.; Di Fonzo, N.; Fares, C. Durum Wheat Lipoxygenase Activity and Other Quality Parameters That Affect Pasta Color. *Cereal Chem.* **1999**, *76*, 335–340. [CrossRef]
40. Armero, E.; Collar, C. Texture Properties of Formulated Wheat Doughs. *Z. Für Leb. Forsch. A* **1997**, *204*, 136–145. [CrossRef]
41. Hajji, T.; Sfayhi-Terras, D.; EL Felah, M.; Rezgui, S.; Ferchichi, A. Incorporation of β-Glucans into Pasta Extracted from Two Tunisian Barley Cultivars. *Int. J. Food Eng.* **2016**, *12*, 701–710. [CrossRef]
42. Cleary, L.; Brennan, C. The Influence of a (1→3)(1→4)-β-d-Glucan Rich Fraction from Barley on the Physico-Chemical Properties and in Vitro Reducing Sugars Release of Durum Wheat Pasta. *Int. J. Food Sci. Technol.* **2006**, *41*, 910–918. [CrossRef]
43. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2017.

44. Kaspar, T.C.; Jaynes, D.B.; Parkin, T.B.; Moorman, T.B.; Singer, J.W. Effectiveness of oat and rye cover crops in reducing nitrate losses in drainage water. *Agric. Water Manag.* **2012**, *110*, 25–33. [CrossRef]
45. Landi, A. Durum Wheat, semolina and pasta quality characteristics for an Italian food company. In *Durum Wheat Quality in the Mediterranean Region*; Di Fonzo, N., Kaan, F., Nachit, M., Eds.; CIHEAM: Zaragoza, Spain, 1995; pp. 33–42.
46. Wozniak, A. The Effect of Tillage Systems on Yield and Quality of Durum Wheat Cultivars. *Turk. J. Agric. For.* **2013**, *37*, 133–138. [CrossRef]
47. Colecchia, S.A.; De Vita, P.; Rinaldi, M. Effects of Tillage Systems in Durum Wheat under Rainfed Mediterranean Conditions. *Cereal Res. Commun.* **2015**, *43*, 704–716. [CrossRef]
48. Brooks, A.; Jenner, C.; Aspinall, D. Effects of Water Deficit on Endosperm Starch Granules and on Grain Physiology of Wheat and Barley. *Funct. Plant Biol.* **1982**, *9*, 423–436. [CrossRef]
49. Kherif, O.; Keskes, M.I.; Pansu, M.; Ouaret, W.; Rebouh, Y.-N.; Dokukin, P.; Kucher, D.; Latati, M. Agroecological modeling of nitrogen and carbon transfers between decomposer micro-organisms, plant symbionts, soil and atmosphere in an intercropping system. *Ecol. Model.* **2021**, *440*, 109390. [CrossRef]
50. Latati, M.; Dokukin, P.; Aouiche, A.; Rebouh, N.Y.; Takouachet, R.; Hafnaoui, E.; Hamdani, F.Z.; Bacha, F.; Ounane, S.M. Species Interactions Improve Above-Ground Biomass and Land Use Efficiency in Intercropped Wheat and Chickpea under Low Soil Inputs. *Agronomy* **2019**, *9*, 765. [CrossRef]
51. Thierfelder, C.; Wall, P.C. Effects of Conservation Agriculture Techniques on Infiltration and Soil Water Content in Zambia and Zimbabwe. *Soil Tillage Res.* **2009**, *105*, 217–227. [CrossRef]
52. Moreira, S.; Kiehl, J.; Prochnow, L.; Pauletti, V.; Neto, L.; Resende, Á. Soybean Macronutrient Availability and Yield as Affected by Tillage System. *Acta Sci. Agron.* **2019**, *42*, e42973. [CrossRef]
53. Sissons, M.; Kadkol, G.; Taylor, J. Genotype by Environment Effects on Durum Wheat Quality and Yield-Implications for Breeding. *Crop Breed. Genet. Genom.* **2020**, *2*, 2020018. [CrossRef]
54. Park, E.Y.; Baik, B.-K.; Machado, S.; Gollany, H.T.; Fuerst, E.P. Functional and Nutritional Characteristics of Soft Wheat Grown in No-Till and Conventional Cropping Systems. *Cereal Chem.* **2015**, *92*, 332–338. [CrossRef]
55. Trad, H.; Ayed, S.; Teixeira da Silva, J.; Othmani, A.; Bouhaouel, I.; Helel, R.; Slim-Amara, H. Quality Assessment of Durum Wheat Landraces and Modern Varieties through Physico-Chemical Properties. *IOSR J. Agric. Vet. Sci.* **2022**, *15*, 56–67. [CrossRef]
56. Wang, K.; Fu, B.X. Inter-Relationships between Test Weight, Thousand Kernel Weight, Kernel Size Distribution and Their Effects on Durum Wheat Milling, Semolina Composition and Pasta Processing Quality. *Foods* **2020**, *9*, 1308. [CrossRef] [PubMed]
57. Kerbouai, I.; Cheikh M'hamed, H.; Jenfaoui, H.; Riahi, J.; Mokrani, K.; Jribi, S.; Arfaoui, S.; Sassi, K.; Ben Ismail, H. Long-Term Effect of Conservation Agriculture on the Composition and Nutritional Value of Durum Wheat Grains Grown over Two Years in a Mediterranean Environment. *J. Sci. Food Agric.* **2022**, *102*, 7379–7386. [CrossRef] [PubMed]
58. Victoriano, L.G.; Vera, N.G.; Simental, S.S.; Hernández, J.P.; Lira, A.Q.; Martini, J.P. Quality Properties of Doughs and Noodles Using Chayotextle (*Sechiem edule*) Flours. *Food Sci. Technol.* **2021**, *41*, 158–166. [CrossRef]
59. Li, Q.; Liu, R.; Wu, T.; Zhang, M. Interactions between Soluble Dietary Fibers and Wheat Gluten in Dough Studied by Confocal Laser Scanning Microscopy. *Food Res. Int.* **2017**, *95*, 19–27. [CrossRef]
60. Barak, S.; Mudgil, D.; Khatkar, B.S. Influence of Gliadin and Glutenin Fractions on Rheological, Pasting, and Textural Properties of Dough. *Int. J. Food Prop.* **2014**, *17*, 1428–1438. [CrossRef]
61. Mironeasa, S.; Ungureanu-Iuga, M.; Zaharia, D.; Mironeasa, C. Rheological Analysis of Wheat Flour Dough as Influenced by Grape Peels of Different Particle Sizes and Addition Levels. *Food Bioprocess Technol.* **2019**, *12*, 228–245. [CrossRef]
62. García-Molina, M.D.; Barro, F. Characterization of Changes in Gluten Proteins in Low-Gliadin Transgenic Wheat Lines in Response to Application of Different Nitrogen Regimes. *Front. Plant. Sci.* **2017**, *8*, 257–269. [CrossRef] [PubMed]
63. Liu, D.; Song, S.; Tao, L.; Yu, L.; Wang, J. Effects of Common Buckwheat Bran on Wheat Dough Properties and Noodle Quality Compared with Common Buckwheat Hull. *LWT* **2022**, *155*, 112971. [CrossRef]
64. Hüttner, E.K.; Bello, F.D.; Arendt, E.K. Rheological Properties and Bread Making Performance of Commercial Wholegrain Oat Flours. *J. Cereal Sci.* **2010**, *52*, 65–71. [CrossRef]
65. Guardianelli, L.; Puppo, M.C.; Salinas, M.V. Influence of Pistachio By-Product from Edible Oil Industry on Rheological, Hydration, and Thermal Properties of Wheat Dough. *LWT* **2021**, *150*, 111917. [CrossRef]
66. Souza, E.J.; Martin, J.M.; Guttieri, M.J.; O'Brien, K.M.; Habernicht, D.K.; Lanning, S.P.; McLean, R.; Carlson, G.R.; Talbert, L.E. Influence of Genotype, Environment, and Nitrogen Management on Spring Wheat Quality. *Crop Sci.* **2004**, *44*, 425–432. [CrossRef]
67. Ficco, D.B.M.; Mastrangelo, A.M.; Trono, D.; Borrelli, G.M.; De Vita, P.; Fares, C.; Beleggia, R.; Platani, C.; Papa, R. The Colours of Durum Wheat: A Review. *Crop Pasture Sci.* **2014**, *65*, 1–15. [CrossRef]
68. Calzarano, F.; Stagnari, F.; D'Egidio, S.; Pagnani, G.; Galieni, A.; Di Marco, S.; Metruccio, E.; Pisante, M. Durum Wheat Quality, Yield and Sanitary Status under Conservation Agriculture. *Agriculture* **2018**, *8*, 140. [CrossRef]
69. Rouphael, Y.; Schwarz, D.; Krumbein, A.; Colla, G. Impact of Grafting on Product Quality of Fruit Vegetables. *Sci. Hortic.* **2010**, *127*, 172–179. [CrossRef]
70. Johansson, E.; Branlard, G.; Cuniberti, M.; Flagella, Z.; Hüsken, A.; Nurit, E.; Peña, R.J.; Sissons, M.; Vazquez, D. Genotypic and Environmental Effects on Wheat Technological and Nutritional Quality. In *Wheat Quality for Improving Processing and Human Health*, 1st ed.; Igrejas, G., Ikeda, T.M., Guzmán, C., Eds.; Springer: Berlin/Heidelberg, Germany, 2020; Chapter 8; pp. 171–204.

71. Gulia, N.; Khatkar, B.S. Quantitative and Qualitative Assessment of Wheat Gluten Proteins and Their Contribution to Instant Noodle Quality. *Int. J. Food Prop.* **2015**, *18*, 1648–1663. [CrossRef]
72. Chandrashekar, A.; Kirleis, A.W. Influence of Protein on Starch Gelatinization in Sorghum. *Influ. Protein Starch Gelatinization Sorghum* **1988**, *65*, 457–462.
73. Sözer, N.; Kaya, A. Changes in Cooking and Textural Properties of Spaghetti Cooked with Different Levels of Salt in the Cooking Water. *J. Texture Stud.* **2003**, *34*, 381–390. [CrossRef]
74. Kaplan Evlice, A. The Effect of Durum Wheat Genotypes on Cooking Quality of Pasta. *Eur. Food Res. Technol.* **2022**, *248*, 815–824. [CrossRef]
75. Padalino, L.; Mastromatteo, M.; Lecce, L.; Spinelli, S.; Contò, F.; Del Nobile, M.A. Effect of Durum Wheat Cultivars on Physico-Chemical and Sensory Properties of Spaghetti: Effect of Wheat Cultivars on Spaghetti Properties. *J. Sci. Food Agric.* **2014**, *94*, 2196–2204. [CrossRef] [PubMed]