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REVIEW

Effect of No Tillage and Conventional Tillage on Wheat Grain Yield Variability: A Review

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ABSTRACT

Conservation Agriculture (CA) covers more than 205 million hectares in the world. This made it possible to face and mitigate the challenges of climate change, reducing soil erosion and providing multiple ecosystem services. The first elementary factor influenced is the yield evaluation. It has a direct effect on farmers' choices for sustainable production. The present article records a review focused on wheat yield average positive change compared between conventional tillage (CT) and no tillage (NT) systems. The international database collected showed that NT is adaptable everywhere. The results of wheat yield differentiation showed the influence of crop rotation depending on stations located in different climatic zones. In more than 40 years of research, specialists have succeeded in demonstrating the importance of crop productivity like wheat. The whole integrates also experimentations where the initiation starts more than ten years.

Keywords: Climate change; No tillage; Crop rotation; Wheat; Yield

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1. Introduction

The agricultural challenges faced many obstacles to maintaining sustainable productivity and preserving the environment [1]. Climate change has a hard impact on the environment and economic ways as it was reported by Schlegel et al., and Moussadek et al. [2,3]. These alterations particularly affect productivity at the international market level. Today, technical and technological progress is being recognized for a better confrontation to these phenomena [4]. Since the end of the Second World War, a certain modernization of agriculture has been established. It concerned also the pollution of groundwater and the disturbance of the nitrogen cycle and carbon cycle. They all are repercussed on developing new strategies [5].

The continual evolution made it possible to adopt new alternative models that can combine several options under CA. It allowed permanent soil covered for years, ensuring sustainability and limiting the use of inputs [3]. The NT system used to take in account the agriculture conditions. The results obtained during the period 1960–2000 made it possible to translate how we can have productivity on the same surface area under CA. The basics of NT include the importance of adopting this practice for many kinds of environments allowing the minimum optimization of inputs used [1,5].

The extension and the determination of CA could after years be resilient to drought effect with better water storage as it was explained by Bouzza [6]. It helps to protect the growing season. Yield evaluation is linked to growth effects.

These are taken into consideration for cereal productions where NT was tested a lot under different aspects. Cereals yield interest represents a large part of agricultural productivity for many countries [7]. According to a couple of programs developed in Mediterranean areas wheat yield profitability varies between 8 and 20% compared to CT [3]. The variability of wheat yield is also attached to the different climates and crop rotation. This work aims to compare the wheat yield of two systems (CT/NT) under each climate and crop rotation adapted.

2. Materials and method

The set of data used was carefully collected and checked from the original papers. That integrates different stations all over the world localized in Morocco, Tunisia, Algeria, Spain, Mexico, USA, Canada, China, Brazil and Australia. It was actualized following the process reported by Su et al. [8], Pittelkow et al. [9] and also Ponisio et al. [10] in their meta-analysis. This is all, in addition to more values of the Maghreb data situation (**Table 1**). It implied the common factors of location, crop sequences, wheat yield under NT and CT, soil texture and climate type. After years of experimentations, searchers analyzed the value of the type of rotation that should be specified. The grain wheat yield variability (%) (GWYV) calculated: ((NTyield-CTyield)/CTyield) × 100 shows us the guidelines in our case depending on crop rotation with qualified soils (Clay and loam) (**Table 1**).

3. Results and discussions

The world is targeted with serious warming signs for projections of the future. The vulnerability indicates strongly the decrease in crop development with an approaching influence of drought. The adoption of NT is a resolution that responds to the distress situation. Climate change is directly relied on agricultural challenges. Uncertainties persist and impact the attention on soil and water resources. The recent data reported by Schmidt et al. [64] point to the alarming temperature deviation between 1930 and 2023.

Over the years, NT proved its place in CA and how it can cope with different phenomena. This work continuously joins the meta-analysis carried out by Su et al. [10]. It marks the interest of the advances of the NT in the Maghreb area. Many conclusions are retained in the long term [15]:

-Reducing energy consumption and inputs used.

-Improving more greenhouse gas balance.

-Restoring organic matter which efficiently is favorable on soil organic stocks.

-Protecting soil against erosion by monitoring crop rotation and residues.

-Ensuring crop yield productivity.

The profitability of wheat yield under CA evolution describes the perspectives for sustainable agriculture.

Table 1. The grain wheat yield variability (%) evaluation under NT and CT.

Location	Year of activity	Years of NT	Crop rotation system	Yield on NT (t/ha)	GWYV (%)	Authors
Algeria						
Setif	2018		Wheat-Tritical-Pea	1,50	24	*Chouter, et al.,* [11]
	2017		Wheat-Lentil	2,68	10	
	2016		Continuous wheat	1,31	70	
	2012			2,20	13	*Taibi, et al.,* [12]
	2011			2,00	–17	
	2010			3,20	28	
	2009			3,75	56	
	2008			1,70	17	
	2010	2		0,30	19	*Chennafi, et al.,* [13]
	2009			0,22	–4	
Oued Smar	2017	-	Wheat-bersim	6,41	5	*Yachi,* [14]
				5,59	1	
Morocco						
Abda	1982	10	Wheat-fallow	3,10	29	*Mrabet,* [15]
		19	Continuous wheat	1,60	0	
Ain Sbit	2021	1	Wheat - lentil	6,99	-	*Raji,* [16]
				6,62	1912	
		2		4,58	316	
		1		7,17	229	
				4,06	152	
		2		7,20	140	
				5,36	48	
		1		11,89	18	
		2		2,20	17	
				7,44	–5	
Chaouia	1996	2	Continuous wheat	6,88	10	*Mrabet,* [17]
				2,03	–1	
	1995	1		12,51	–2	
				4,15	–5	
	1982	10	Wheat-fallow	3,70	42	*Bouazza,* [6]
	-	3	Wheat-chickpeas	1,87	146	*Mrabet,* [18]
	-	9		2,53	72	*Mrabet,* [19]
	-	9	Different rotation	2,21	16	*Mrabet,* [20]
	1982	10	Continuous wheat	1,90	36	*Mrabet,* [17]
		19		2,47	5	
Gharb	-	3		2,8	24	*Razine and Raguine,* [21]
Merchouch	2020	18	Durum wheat-legume	4,15	26	*Maher, et al.,* [22]
				4,62	7	
				4,18	7	
				4,22	5	
				3,17	–1	

Table 1 continued

Location	**Year of activity**	**Years of NT**	**Crop rotation system**	**Yield on NT (t/ha)**	**GWYV (%)**	**Authors**
Merchouch	2018	15	Wheat-chickpea-barley-lentil	2,15	13	*Devkota, et al.,* [23]
	2016	13		3,00	33	
	2015	12		0,90	80	
	2014	11		2,80	47	
	2010	7	Soft wheat-lentil	3,80	6	*Moussadek, et al.,* [3]
	2009	6		1,70	–11	
	2008	5		4,70	12	
	2007	4		2,60	44	
	2006	3		0,50	25	
	2005	2		4,60	15	
	2004	1		1,50	50	
Saïs	-	4	Different rotation	2,55	2	*Mrabet and Moussadek,* [24]
	-			2,72	–1	
	2020	-		4,11	21	*Sellami, et al.,* [25]
	2019	-		2,60	27	
Zaer	-	4	Wheat-lentil	1,97	40	*Mrabet and Moussadek,* [24]
	-			2,99	10	
	-			2,71	9	
Tunisia						
Kef	2014	-	Fababean-durum wheat-barley	2,70	5	*Chaieb, et al.,* [26]
Koudiat	2013		Durum wheat-fababean	3,82	7	*Mouelhi, et al.,* [27]
			Durum wheat-barley	1,96	7	
			Durum wheat-oat	2,17	6	
	2012		Durum wheat-barley	2,46	8	
			Durum wheat-fababean	4,29	7	
			Durum wheat-oat	2,19	–7	
	2011		Durum wheat-fababean	3,75	19	
			Durum wheat-barley	2,98	19	
			Durum wheat-oat	2,85	6	
	2010		Durum wheat-fababean	3,43	10	
			Durum wheat-oat	3,03	7	
			Durum wheat-barley	3,21	6	
	2009		Durum wheat-oat	3,42	9	
			Durum wheat-fababean	3,46	4	
			Durum wheat-barley	3,40	–12	
Krib	-	4	Durum wheat-pea-oat	3,68	6	*Ben Moussa-Machraoui, et al.,* [28]
Mahassen	-		Durum wheat-barley	1,43	72	
-	-	5	Continuous wheat	2,18	12	*M'hedhbi, et al.,* [29]
Mateur		2		3,90	18	*Vadon, et al.,* [30]
Australia						

Table 1 continued

Location	Year of activity	Years of NT	Crop rotation system	Yield on NT (t/ha)	GWYV (%)	Authors
Biloela	1999	17	Continuous wheat	2,50	67	*Radford and Thornton* [1]
	1998	16		1,77	25	
	1997	15		2,04	31	
	1996	14	Maize-wheat	3,17	57	
	1991	9	Continuous wheat	2,02	5	
	1990	8		1,60	29	
	1987	5	Sorghum-wheat	0,65	2	
Queensland, Gindie	1991	2	Wheat-chickpeas	1,60	4	*Armstrong, et al., 2003* [31]
Victoria, Rutherglen	1983	1	Continuous wheat	2,22	7	*Coventry, et al., 1992* [32]
Western Australia, Merredin	1982	6		1,03	76	*Hamblin, et al., 1984* [33]
	1981	5		0,98	72	
Brazil						
Parana, Londrina, Embrapa Soybean	2008	20	Winter wheat-summer soybean; winter lupine -summer maize; winter oat-summer soybean	2,13	36	*Franchini, et al.,* [34]
	2006	18		2,51	27	
	2005	17		2,88	1	
	2004	16		3,27	6	
		16		3,21	3	
	2003	15		1,02	4	
	1997	9		1,97	51	
				1,85	40	
	1990	2		0,65	7	
Canada						
Alberta, Beaverlodge	2005	2	Barley-wheat-canola	1,93	35	*Soon, et al.,* [35]
Alberta, Champion	1993	1	Continuous wheat	3,74	71	*Blackshaw, et al.,* [36]
Alberta, Rycroft	1994	6	Fallow/green manure-canola-wheat-barley	3,25	15	*Arshad and Gill,* [37]
Alberta, Three Hills	2003	10	Continuous wheat	2,76	3	*Wang, et al.,* [38]
	2002	9		0, 97	147	
	2001	8		2,23	18	
	2000	7		2,32	44	
Saskatchewan, Cantuar	1990	10	Fallow-wheat	0,60	15	*McConkey, et al.,* [39]
	1989	9	Wheat-fallow	1,27	11	
Saskatchewan, Melfort	1997	5	Canola-wheat-barley-barley; Canola-barley-pea-wheat; Canola-pea-flax-barley	5,10	2	*Bailey, et al.,* [40]
	1996	4		5,20	7	
	1994	2		3,96	14	
	2001	8	Canola-wheat-barley-barley; canola-barley-pea-wheat; canola-pea-flax-barley	2,07	61	*Kutcher, et al.,* [41]
Saskatchewan, Rosthern	2007	4	Canola-wheat-wheat	1,98	12	*Baan, et al.,* [42]
	2006	3		3,29	1	

Table 1 continued

Location	Year of activity	Years of NT	Crop rotation system	Yield on NT (t/ha)	GWYV (%)	Authors
Saskatchewan, Scott	1990	13	Wheat-oilseed-wheat; fallow oilseed-wheat	2,66	17	*Brandt,* [43]
	1990			2,71	12	
	1987	10		2,03	23	
	1981	4		2,18	18	
				2,45	2	
Saskatchewan, Stewart Valley	1993	13	Continuous wheat	2,76	–1	*McConkey, et al.,* [39]
			Fallow-wheat	3,05	–18	
	1990	10	Continuous wheat	2,38	10	
			Fallow-wheat	3,55	7	
	1989	9		2,28	37	
Saskatchewan, Swift Current	1993	3	Continuous wheat	2,59	0	
		13		2,46	1	
	1990	10		2,28	18	*McConkey, et al.,* [44]
				2,61	5	*McConkey, et al.,* [39]
		9		2,58	14	
		7		1,60	14	
	1987		Fallow-wheat	2,45	1	
	1990	10	Continuous wheat	2,61	5	*Selles, et al.,* [45]
			Wheat-fallow	2,88	–2	
	1988	8	Continuous wheat	0,65	23	
		8	Wheat-fallow	1,66	15	
	1987	7		2,45	1	
Saskatchewan, Tisdale	2007	4	Canola-wheat-wheat	1,88	10	*Baan, et al.,* [42]
China						
Dongping, Shandong Province	2016	5	Maize-wheat	10,56	11	*Latifmanesh, et al.* [46]
				9,53	10	
	2015	4		10,27	11	
				11,00	8	
				9,61	5	
Gansu	2016	1		8,73	18	*Guo, et al.* [47]
Heyang, Shanxi		10		2,74	13	*Sun,* [48]
				2,88	6	
	2012	6		3,38	16	
				3,28	7	
	2010	4		3,28	16	
	2009	3		2,54	9	
				2,18	5	
	2008	2		2,65	3	
				3,26	2	
Tai'an, Shandong Province	2015	14	Winter wheat-summer maize	8,3	0	*Liu,* [49]
	2014	13		8,2	1	
				8,2	9	*Xu,* [50]

Table 1 continued

Location	Year of activity	Years of NT	Crop rotation system	Yield on NT (t/ha)	GWYV (%)	Authors
Mexico						
Ciudad Obregon	2008	4	Continuous wheat	4,95	25	*Verhulst, et al.,* [51]
Ciudad Obregon	2008	4	Continuous wheat	4,87	19	*Verhulst, et al.,* [51]
Ciudad Obregon	2008	4	Continuous wheat	7,57	3	*Verhulst, et al.,* [51]
Ciudad Obregon	2008	4	Continuous wheat	7,52	1	*Verhulst, et al.,* [51]
Ciudad Obregon	2007	3	Continuous wheat	5,18	10	*Verhulst, et al.,* [51]
Ciudad Obregon	2007	3	Continuous wheat	4,63	1	*Verhulst, et al.,* [51]
Ciudad Obregon	2006	2	Continuous wheat	8,20	6	*Verhulst, et al.,* [51]
Ciudad Obregon	2006	2	Continuous wheat	4,77	1	*Verhulst, et al.,* [51]
Spain						
Agramunt	2002	13	Barley-wheat	2,6	30	*Cantero-Martinez, et al.,* [52]
Cordoba	2005	20	Wheat-sunflower; wheat-fababean; wheat-chickpea; wheat-fallow	2,63	20	*López-Bellido, et al.,* [53]
Cordoba	2005	20	Wheat-sunflower; wheat-fababean; wheat-chickpea; wheat-fallow	2,85	17	*López-Bellido, et al.,* [53]
Cordoba	2003	18	Wheat-sunflower; wheat-fababean; wheat-chickpea; wheat-fallow	4,94	21	*López-Bellido, et al.,* [53]
Cordoba	1991	6	Wheat-sunflower; wheat-fababean; wheat-chickpea; wheat-fallow	1,91	–1	*López-Bellido, et al.,* [54]
Cordoba	1990	5	Wheat-sunflower; wheat-fababean; wheat-chickpea; wheat-fallow	2,51	–10	*López-Bellido, et al.,* [54]
Cordoba	1989	4	Wheat-sunflower; wheat-fababean; wheat-chickpea; wheat-fallow	4,50	–11	*López-Bellido, et al.,* [54]
Cordoba	1987	2	Wheat-sunflower; wheat-fababean; wheat-chickpea; wheat-fallow	4,70	0	*López-Bellido, et al.,* [54]
Cordoba	2007	22	Wheat-chickpea	3,48	41	*Melero, et al.,* [55]
Cordoba	2007	22	Wheat-chickpea	8,49	32	*Melero, et al.,* [55]
Cordoba	2007	22	Wheat-fababean	4,70	20	*Melero, et al.,* [55]
Cordoba	2007	22	Wheat-fallow	11,76	18	*Melero, et al.,* [55]
Cordoba	2007	22	Wheat-wheat	3,75	14	*Melero, et al.,* [55]
Cordoba	2007	22	Wheat-sunflower	2,07	11	*Melero, et al.,* [55]
Cordoba	2007	22	Wheat-wheat	9,34	10	*Melero, et al.,* [55]
Cordoba	2007	22	Wheat-sunflower	5,11	5	*Melero, et al.,* [55]
Selvanera	2003	17	Barley-canola-wheat,	2,48	–9	*Cantero-Martinez, et al.,* [52]
Selvanera	2001	15	Barley-canola-wheat,	5,13	5	*Cantero-Martinez, et al.,* [52]
Selvanera	1999	13	Barley-canola-wheat,	3,16	2	*Cantero-Martinez, et al.,* [52]
Selvanera	1993	7	Barley-canola-wheat,	5,42	22	*Cantero-Martinez, et al.,* [52]
USA						
Kansas Tribune	2013	23	Wheat-sorghum-fallow	1,18	74	*Schlegel, et al.,* [2]
Kansas Tribune	2008	18	Wheat-sorghum-fallow	1,48	160	*Schlegel, et al.,* [2]
Kansas Tribune	1992	2	Wheat-sorghum-fallow	3,91	36	*Schlegel, et al.,* [2]
Kansas, Garden City	1988	4	Wheat-sorghum-fallow	1,53	89	*Norwood,* [56]
Kansas, Saline County	2005	2	Sorghum-winter wheat-winter wheat; maize-soybean-winter wheat-winter wheat	3,06	12	*Carignano, et al.,* [57]
Kansas, Tribune	1994	4	Wheat-fallow; wheat-sorghum-fallow; wheat-wheat	3,49	11	*Schlegel, et al.,* [58]

Table 1 continued

Location	Year of activity	Years of NT	Crop rotation system	Yield on NT (t/ha)	GWYV (%)	Authors
North Dakota, Mandan	1995	12	Spring wheat-winter wheat-sunflower	2,28	34	*Halvorson, et al.,* [59]
	1989	6		1,26	7	
	1988	5		1,14	47	
Oklahoma	2016	6	Winter wheat-cowpea	5,82	22	*Kandel, et al.,* [60]
South Carolina, Florence	1990	12	Maize-wheat-cotton	2,87	48	*Karlen, et al.,* [61]
Texas, Burleson County	2000	17	Continuous wheat	1,12	78	*Ribera, et al.,* [62]
	1996	13	Sorghum-wheat-soybean; wheat-soybean	2,26	13	
	1995	12		2,75	35	
	1994	11		2,4	28	
			Continuous wheat	1,84	9	
	1992	5	Sorghum-wheat-soybean; wheat-soybean	2,60	9	
	1988	8	Continuous wheat	2,41	27	
Texas, Bushland	1995	6	Wheat-sorghum-fallow	0,80	186	*Baumhardt and Jones,* [63]
	1993	11		2,07	37	
	1992	10	Continious wheat	1,84	63	*Jones and Popham,* [64]
	1991	8	Wheat-soybean-fallow	2,06	29	
	1989	6	Wheat-fallow	1,26	24	
	1987	6	Continious wheat	1,51	29	

3.1 The general interest of wheat yield under NT

Research carried out over the last four decades on CA, has shown the benefits of the direct interactivity between farmers, specialists and State support. This cohesion made it possible to invest efficiently as detailed by Mrabet et al. [5]. The adaptability of NT on multiple levels is oriented to knowing how to achieve crop productivity despite drought situations [3]. Wheat yield results obtained under NT and CT evaluated in the same conditions as Mediterranean ones confirm the process. In 1990 Bouzza [6] centralized the intensity of water storage and the GWYV positively under NT compared to CT. These are highlighted more by Mrabet et al. [18], with +146%. All the GWYV calculated are classified in **Table 1**. This visibility is marked by potentialities that should be adopted in all the continents and turn the attention to how to extend the system [14]. These relevant aspects are also explored by Moussadek et al. [3], after only four years of NT, the yield variation takes the reflection to +0,44 at Merchouch station between the period of 2004–2008 (Morocco). This is in continual adequation of what Devkota et al. [22] , obtained after 18 years at the same station with +80% yield variability. The last five years of successive drought seasons in North Africa (Morocco, Algeria and Tunisia) support the previous conclusions. Raji [16], results on the table presented note a value of +1912% at Ain Sbit (Morocco), some farmers didn't harvest any wheat yield under CT at the period concerned. It's in total adequacy with Chouter et al. [11], experimentations at Setif (Algeria). They join the fact that under drought effect NT could be more performant. They join previous searchers, it is attached to the nature of crop rotation and climate influence. All of these approaches were also expected in Australia, Brazil, Canada, China, Mexico, Spain and the USA as cited in **Table 1**.

3.2 The long-term influence of crop rotation and climate under NT

Crop rotation and residue retention affect the stock organic carbon and can increase wheat yield [3]. When both are controlled, it could make the vision of high wheat productivity for a long-term effect. This intensity revealed the power of GWYV and the crop rotation choice under NT. Schlegel et al.[2], experimentation defined a variation of +160% on the wheat-sorghum and fallow rotation in the loamy soil of the Kansas area (USA). It was in continual adequacy with values obtained by Norwood [55], with +89% at the same place. In the same directive, Baumhardt and Jones [62], on Texas's experimentations and monitored precisely the potential of wheat yield advantages compared the two systems. This variability is projected on many crops rotations advanced in **Table 1.** The exploration of crop rotation is accommodated with the veritable crop choice. Years of studies, in warm and temperate zones solicitation by searchers like Sun [47] led to consequences on wheat-maize rotation and mentioned the efficacity of wheat yield evolution under NT. Their perseverance is totally accorded by Latifmanesh and Guo [45-46], in different stations of China. Another rotation marked by specialists is the continuous-wheat rotation. It is comparable depending on the climates where the dry seasons are significant. McConkey et al. [38], confront after more than ten years of NT, two rotations: continuous wheat and wheat-fallow. The values were joined by Selles et al. [44] at Saskatchewan's stations (Canada), where the continental climate is predominant without alarming drought seasons. It reports the evidence of wheat yield attachment detailed by Blacksnaw et al. and Wang et al. [35,37]. They affirmed also that the disposition of climate takes a look at crop spreading. Long-term NT studies, taken up at the level described in the table, leaned researchers into the profitability of the yield and its relativity which is in total coordination with the results in the Mediterranean zone. It detects the comparative yield under three crop rotations: wheat-wheat, wheat-fallow, and cereals-legumes. During the last five years drought circumstances defined the implication of legumes like crop rotation in a resilient system. The semi-arid zones have the last five years, been affected by hard dry effects, experimentations after more than 10 years target when wheat productivity is associated with cereals-legumes systematic rotation. Many of those are explored at semi-arid stations like Merchouch (Morocco). The steps of challenging climate and crop rotation system adapted, in all cases ensuring the positive arrangement of NT compared to CT. It consolidates with every soil aspect and wheat productivity the sustainability of the process in the long term.

4. Conclusions

All the authors cited in this review based on different experimental stations of many countries referenced, agree with the profitability in different stages of wheat yield under NT compared to CT. The valorization of a few inputs used can make an impressive value of GWYV. These yields are conducted by climates and crop rotation influence. It leaves the continuity of ecological, economic and environmental profitability. Indeed, the interest in varietal choice applications is centralized also to improve yield efficiency for the long term.

Author Contributions

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Conflict of Interest

All authors are agreed for the publication of this manuscript version and declare that there are no conflicts of interest.

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