EFFECT OF REDUCED TILLAGE ON WHEAT RHEOLOGICAL PROPERTIES

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ABSTRACT
The effect of tillage systems (TS) on wheat reological properties including farinographic, extensographic and amilographic parameters was studied. Eight different tillage systems were compared in winter wheat (*Triticum aestivum* L.) production on one experimental field (chrenosem) located in the Baranya region of north-eastern Croatia in 2002, 2003 and 2004. The influence of RT on farinogaphic parameters was not significant for the second and thread years. However, TS did not show statistically significant difference in farinograph parameters, except the dough stability in the 3-year average. In the contrary the influence of year shows statistically significant differences on all farinographic parameters. Interaction year and tillage system were significant for dough development, resistance and quality number. Among three vegetation years factor Y was significant different for all extensographic parameters, interaction Y + TS was significant different for the extensibility, while the factor TS did not show significant difference. In the 3-year average, RT did not show statistically significant difference in amilographic parameters, except beginning of gelatinisation. To sum up, DH, CH, CWDS, CwNs and CsNw produced equal quality reological properties wheat and slightly better than CT and these systems could be presented as an even-handed replacement for tilling.

Key words: reduced tillage, winter wheat, reological properties

Abbreviations: CT: conventional tillage; DH: disc harrowing (fine till); CH: Soil loosening (chisel plough); NT: no-tillage; CSDW: conventional tillage for soybean (odd years) and disc harrowing for winter wheat; CWDS: conventional tillage for winter wheat (odd years) and disc harrowing for soybean (even years); CsNw; conventional tillage for soybean (odd years) and no-tillage for winter wheat; CwNs; conventional tillage for winter wheat (odd years) and no-tillage for soybean (even years); TS: tillage system; RT: reduced tillage; Y x TS: Year x tillage system.

INTRODUCTION
Conventional tillage (CT) practices are one of the many emerging environmental agronomic-economic issues that are addressed in contemporary cropping systems [1]. Therefore, there has been an increasing trend towards minimal tillage systems for production in Europe [2]. Wheat production in eastern Croatia in based on CT which includes ploughing (25-30 cm) and standard seedbed preparations (disc harrowing,

harrowing, seeding) and even no-tillage (NT) [3]. Rasmussen [4] claims that reduced tillage (RT) can be successfully applied exclusively to winter wheat and oilseed rape. CT systems have a marked influence on the germination environment of seeds by altering the temperature and moisture of the soil surface [2]. Probert et al [5], Blevins et al [6] and López-Bellido et al [7] argued that the decreased water evaporation from the soil due to the residual cover under NT could increased the soil water content in comparison with CT, especially in dry seasons, which could be the reason for the increased wheat yield. In general, NT systems have a greater positive effect on crop growth and yield when used on soil characterized by low organic matter levels and poor structure, rather than on well-structured soils high in organic matter [8]. No-tillage production results with changes in soil physical properties [9], including increased content of organic matter in soil [10] and aggregating stability and macroporosity [11, 12]. CH, CSDW and CsNw produced equal quality properties and slightly better than CT and these systems could be presented as an even-handed replacement for tilling [13]. The changes may be detrimental, neutral or beneficial for crop growth, yield, soil texture and structure [14, 15, 17] and climatic factors such as rainfall [16] or drought [17]. Our objective was to determine the effect of eight different tillage systems on reological properties of winter wheat.

MATERIALS AND METHODS

Field experiments were conducted at Kneževo site in the Baranya region situated in north-eastern Croatia (45° 32' N and 18° 44' E, 90 m elevation). The study was conducted over a 3 – year period (2001/2002, 2002/2003/ and 2003/2004) as a monofactorial trail with randomized plots divided in block within four replication and with basic plot area of 900 m^2 (18 x50 m), as a stacionary experiment on the dominant soil type of the Baranya region, chrenosem (pH = 8. 14; $pH_{(KCl)}$ = 7.58; organic matter: 120.9 mg kg^{-1} P and 131.8 mg kg^{-1} (determined by Egner-Reihem Domingo Al-method) and 2. 55% $CaCO_3$). Climatic conditions during the experiment at Kneževo site are shown in Table 1. The study began in 2001/2002. The experiment was conducted in the same homogeneous field and at the same location for each experimental year. Prior to the start of the experiment, only conventional tillage was applied. In all three years the forecrop was soybean. Furthermore, winter wheat (*Triticum aestivum* L.) in 2001/2002 for all tillage systems was sown at a rate 300kg ha^{-1} on October 30, 2001, on November 22, 2002 and on October 29, 2003. Fertilization was uniform for all tillage systems and all experimental years (40 kg ha^{-1}N in basic dressing, 81 $kgha^{-1}$N top dressing), $\sum$= 130 kg ha^{-1}P and 130 kg ha^{-1}K). The following were applied with continuity: 1. conventional tillage (CT) plots were cultivated by autumn plugging (30 cm deep), disc harrowing (DH) (15 cm) and disc harrowing to depth of 10 cm. Grain drills John Deer 750A was used for all TS at a depth of 5 cm. 2. Autumn disc harrowing (DH) was applied (fine till) to a depth 15 cm and 10 cm and followed by seeding. 3. Autumn disc harrowing + soil loosening was performed by chisel (CH) to a depth of 20-30 cm, disc harrowing to a depth of 15 cm and followed by seeding. 4. No-tillage was followed by direct seeding. In all experimental years was applied discontinued tillage: 5. Autumn disc harrowing to a depth 15 cm and 10 cm for wheat and followed by seeding, previous year CT for soybean (CSDW). 6. Conventional tillage for wheat and previous year disc harrowing for soybean (CWDS). 7. No-tillage for wheat and previous year conventional tillage for soybean was applied (CsNw). 8. Conventional tillage for wheat and previous year no-tillage for soybean (CwNs). Rheological analyses (Brabender farinograph, extensograph and amylograph) were performed in accordance with the Croatian Official Methods [18]. The influence tillage systems (TS) on the wheat rheological properties were determined by analyses of variance and evaluated by F-test. Significant differences between tillage systems (TS) and observed whet properties were determined by LSD test (P< 0.01**; P <0.05*).

Table 1. Total precipitation (mm) and temperature (°C) from September through February (winter) and the growing season (March through July) at Kneževo site during 2001/2002, 2002/2003 and 2003/2004

	2002	2003	2004	30-yr mean	2002	2003	2004	30-yr mean
	Precipitation (mm)				Temperature (° C)			
Winter	171	281	330	272	6	9	6	6
March	10	4	35	41	9	6	6	6
April	64	9	120	46	11	11	11	11
May	86	33	77	60	19	20	17	17
June	49	19	114	92	22	25	20	20
July	61	61	41	61	24	23	22	21
Growing season	270	126	338	300	19	17	15	15

RESULTS AND DISCUSSION

Over-winter precipitation was 171 mm in 2002, 281 mm in 2003 and 330 mm in 2004 in comparison to the 30-year average of 272. Conversely, over-winter precipitation in 2002 only 171 mm. Total precipitations during the growing season was greater in 2004 year than the 30-yr average of 300 mm and ranged from 126 mm in 2003 to 270 mm in 2002, 2002 and 2003 by 2 - 4 °C than the 30-yr average (Table 1).

Rheological studies

The Brabender farinograph, extensograph and amilograph are used most frequently to characterize flour. Mean values of rheological properties in 2001/02, 2002/03 and 2003/04 are shown in tables 2, 3 and 4. Water absorption capacity is the most important parameter measured by farinograph. Higher flour water absorption indicates a flour of good quality. Values for this parameter were high for all samples in all three vegetation years. The influence of TS was significant in the first year for the dough development, flour stability and quality number at the level of P=0.01, and for the resistance and softening degree at the level P=0.05. Dough development was higher for the CWDS and CwNs in the first year (Table 2) and for NT, CsNw and CwNs in the second year (Table 3). Higher values of dough development and dough stability indicate better flour. Values for dough development and stability were lower in the thread vegetation year for all tillage systems (Table 4). It can be justified by greater precipitation during growing season in the 2004 year (higher than 30-yr average), (Table 1). Dry weather condition has a preferential effect on the gluten quality. Softening degree is also an important parameter for flour quality. It was higher in the thread vegetation year. The influence of TS on farinogaphic parameters was not significant for the second and thread years (Table 5.). However, TS did not show statistically significant difference in farinograph parameters, except the dough stability in the 3-year average. The influence on the dough stability was significant at the level P=0.05. In the contrary the influence of year shows statistically significant differences on all farinographic parameters at the level P=0.01. Interaction year and tillage system were significant for dough development, resistance and quality number at the level P=0.05 (Table 5).

The important extensographic parameters are: energy, resistance, extensibility and the ratio resistance and extensibility. The strong flour shows high value of energy and resistance. For the bakery use the optimal ratio resistance/extensibility should be 1.5 to 2.5. All extensographic parameters indicate flour of good quality for all vegetation years. Influence of TS on extensographic indices did not show statistically significant difference, except value for the flour extensibility in the 2003/04 vegetation years. Among three vegetation years factor Y was significant different for all extensographic parameters, interaction Y + TS was significant different for the extensibility at the level 0.05, while the factor TS did not show significant difference.

Amilographic parameters reflect amylase activity, which influence gelatization process. The important indicators are temperature for the start of gelatinisation beginning, stability time and maximal viscosity. The gelatinisation beginning was about 60 °C and the maximal temperature up to 87 °C, for all TS and experimental years (Table 2, 3 and 4). These values are in accordance with literature values for wheat starch. The influence of TS on the gelatinisation beginning was significantly different in the second year (Table 5). Stability time (time of gel formation) had optimal values for all TS. It is advisable that stability time be longer. Values for the maximal viscosity are inversely proportional to amylase content. Amylase share is a cultivar property, although it can be increased due to unfavourable weather conditions, especially by heavy precipitation during harvest time [19]. The maximal viscosity values between 400 and 600 AU are considered to be optimal for bakery products. Amylase content can be increased due to unfavourable weather condition, especially by heavy precipitation during growing season. Values for the maximal viscosity were high especially for the second experimental year for all TS, what is mean that the amylase content was low, which can be justified by dry climatic condition during vegetation period (Table 3). The precipitation was the lowest among experimental years (Table 1). In the contrary, in the thread experimental year, the values for maximal viscosity amount about 900 AU, which was nearer to optimal values for bakery products (Table 4). In the 3-year average, TS did not show statistically significant difference in amilographic parameters, except beginning of gelatinisation (P=0.01). Among three vegetation years factor Y was significant different for stability time and maximal viscosity and Y + TS was significant different for the swollen beginning at the level 0.01. TS did not show statistically significant difference on the extraction rate. In the 3-year average, factor year influences extraction rate at the level 0.01.

Table 2. Mean values of rheological properties of winter wheat with reduced tillage at Kneževo location in 2001/2002

	Farinograph						Extensograph				Amylograph				
Tillage systems	Water absorb capacity (%)	Dough development (min)	Stability (min)	Resist (min)	Softening degree (FU)	Quality number	Energy (cm^2)	Resist. (EU)	Extensibility (mm)	Resist./ Exstens	Start swollen (min)	Temp Max (C)	Stability Time (min)	Maximal Viscosity (AU)	Flour excretion rate (%)
CT	61.5	2.8	2-0	4.8	79	63.9	82.8	294	165	1.8	59.6	86.3	17.8	1703	76.75
DH	61-3	2.9	2.3	5.1	83	63.6	81.0	275	168	1.6	58.5	84.9	17.6	1661	77.29
CH	61.6	3.1	2.3	5.3	79	64.8	81.1	274	166	1.6	59.6	85.5	17.3	1679	77.48
NT	61.3	2.3	3.4	5.8	69	68.5	82.5	299	160	1.9	59.1	86.7	18.4	1726	76.76
CSDW	60.5	3.2	2.4	5.6	75	66.5	83.2	326	151	2.2	60.4	87.0	17.7	1676	77.23
CWDS	61.2	3.7	1.6	5.3	75	67.2	83.6	283	166	1.7	60.3	86.7	17.6	1708	76.63
CsNw	61.8	2.6	2.3	4.7	80	63.4	74.7	290	162	1.8	59.5	86.4	18.0	1671	77.60
CwNs	61.0	3.7	2.0	5.7	72	68.8	83.2	307	158	1.9	59.6	77.8	17.8	1667	76.65
LSDP=0.05	0.93	0.72	0.71	0.62	8.15	3.05	13.33	48.47	12.92	0.38	1.97	8.42	0.82	67.39	0.74
P=0.01	0.126	0.98	0.97	0.84	11.05	4.14	18.07	65.68	17.05	0.52	2.67	11.42	1.11	91.33	1.00

FE: farinographic units; EU: exstensograpgic units; AU: amilographic units

Table 3. Mean values of rheological properties of winter wheat with reduced tillage at Kneževo location in 2002/2003

	Farinograph						Extensograph				Amylograph				
Tillage systems	Water absorb capacit y (%)	Dough development (min)	Stabilit y (min)	Resist (min)	Softenin g degree (FU)	Quality number	Energy (cm^2)	Resist. (EU)	Extensibili ty (mm)	Resist./ Exstens	Start swollen (min)	Temp Max (C)	Stability Time (min)	Maximal Viscosity (AU)	Flour excretion rate (%)
CT	61.7	3.0	2-0	5.1	68	67.6	88.7	310	156	2.0	61.6	85.7	16.1	2714	76.32
DH	61-7	2.6	2.8	5.4	61	70.6	91.2	318	158	2.0	63.9	87.3	15.6	2710	76.02
CH	61.7	2.9	2.0	4.9	61	70.7	90.8	323	156	2.1	63.0	86.3	15.6	2738	76.28
NT	63.2	3.6	2.1	5.7	63	69.6	83.5	275	164	1.7	62.1	87.1	16.7	2549	76.52
CSDW	62.7	3.3	1.7	5.0	69	66.5	75.4	263	160	1.6	63.3	87.8	16.4	2528	76.53
CWDS	61.3	2.9	1.4	4.4	73	65.6	86.2	299	157	1.9	60.24	84.5	16.6	2766	76.16
CsNw	62.9	3.9	1.8	5.6	63	69.2	80.3	270	164	1.7	62.7	86.6	15.9	2696	76.10
CwNs	61.5	3.4	1.2	4.6	63	68.5	105.9	337	167	2.0	60.1	85.7	17.1	2754	75.56
LSDP=0.05	2.20	1.07	1.38	1.01	12.69	4.90	24.52	84.17	10.65	0.59	6.70	7.80	1.36	281.38	1.03
P=0.01	2.99	1.45	1.87	1.37	17.19	6.63	33.22	114.06	14.44	0.80	9.08	3.79	1.85	381.31	1.39

FE: farinographic units; EU: exstensograpgic units; AU: amilographic units

Table 4. Mean values of rheological properties of winter wheat with reduced tillage at Kneževo location in 2003/2004

	Farinograph						Extensograph				Amylograph				
Tillage systems	Water absorb capacity (%)	Dough development (min)	Stability (min)	Resist (min)	Softening degree (FU)	Quality number	Energy (cm²)	Resist. (EU)	Extensibility (min)	Resist./ Exstens	Start swollen (min)	Temp Max (C)	Stability Time (min)	Maximal Viscosity (AU)	Flour excretion rate (%)
CT	61.4	1.8	0.6	2.4	94	58.9	83.2	295	159	1.9	60.9	68.4	17.0	891	77.68
DH	62.6	1.8	0.6	2.4	91	58.0	78.1	320	147	2.2	59.7	85.0	16.9	900	77.59
CH	62.0	1.7	0.7	2.3	99	54.1	75.9	324	140	2.3	59.9	85.5	17.1	895	77.78
NT	61.9	1.7	0.7	2.3	94	56.8	77.5	344	139	2.5	60.8	86.4	17.1	954	77.71
CSDW	62.5	1.8	0.7	2.5	83	60.7	83.9	335	146	2.3	60.2	85.5	16.9	998	77.77
CWDS	62.2	1.8	0.7	2.6	84	60.0	86.2	336	152	2.2	61.1	87.5	17.6	974	77.88
CsNw	63.1	1.8	0.6	2.4	93	56.6	78.2	318	146	2.2	61.0	86.9	17.3	1043	77.05
CwNs	62.4	1.9	0.7	2.5	90	56.9	82.5	328	147	2.2	60.1	85.5	17.0	923	77.66
LSDP=0.05	1.74	0.30	0.29	0.45	17.22	6.61	13.60	56.60	11.97	0.50	1.95	2.10	1.05	171.67	1.06
P=0.01	2.35	0.41	0.39	0.62	23.34	8.96	18.43	76.71	16.23	0.68	2.65	2.85	1.63	232.64	1.44

FE: farinographic units; EU: exstensograpgic units; AU: amilographic units

Table 5. Values of F-test for reological properties of winter wheat during to 2002 – 2004 at location Kneževo

Reological properties	2001/2002	2002/2003	2003/2004	Year (Y)	Tillage (TS)	Interaction Y x TS
Water absorb capacity (%)	1.54	0.89	0.73	7.05**	1.21	0.88
Dough develop. (min)	4.03**	1.31	0.41	77.93**	1.67	2.45*
Stability (min)	4.61**	0.99	0.33	65.52**	2.56*	1.61
Resist (min)	3.31*	1.80	0.33	320.93**	1.29	2.29*
Softening degree (FU)	2.61*	0.99	0.83	74.09**	0.67	1.51
Quality number	4.41**	1.23	0.86	92.24**	0.56	2.04*
Energy (cm²)	0.40	1.17	0.69	3.64*	1.31	0.93
Resist. (EU)	1.11	0.89	0.59	4.98**	0.51	1.15
Extensibility (min)	1.66	1.22	2.42*	33.68**	1.27	2.16*
Resist./Exstens	1.73	0.81	1.00	13.83**	0.56	1.41
Start swollen (min)	0.79	7.18**	0.66	0.81	5.19**	6.92**
Temp Max (C)	1-11	1.18	1.34	1.01	1.41	1.03
Stability Time (min)	1.22	1.40	0.35	29.73**	1.45	0.72
Maximal/Viscosity(AU)	0.98	0.90	0.86	1398.71**	0.54	1.10
Flour excretion rate (%)	2.37	0.78	8.86	45.00**	1.01	0.66

**P< 0.01; *P <0.05

CONCLUSION

TS did not show statistically significant difference in farinograph parameters, except the dough stability in the 3-year average. The influence on the dough stability was significant at the level P=0.05. The influence of year shows statistically significant differences on all farinographic parameters at the level P=0.01. Interaction year and tillage system were significant for dough development, resistance and quality number at the level P=0.05. Among three vegetation years factor Y was significant different for all extensographic parameters, interaction Y + TS was significant different for the extensibility at the level P=0.05, while the factor TS did not show significant difference. In the 3-year average, TS did not show statistically significant difference in amilographic parameters, except beginning of gelatinisation (P=0.01). Among three vegetation years factor Y was significant different for stability time and maximal viscosity and factor (Y + TS) was significant different for the swollen beginning at the level 0.01. TS did not show statistically significant difference on the extraction rate. In the 3-year average, factor Y influences extraction rate at the level 0.01. To sum up, DH, CH, CWDS, CwNs and CsNw produced equal quality reological properties wheat and slightly better than CT and these systems could be presented as an even-handed replacement for tilling.

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