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EFFECT OF SOIL TILLAGE AND NITROGEN FERTILIZATION TREATMENTS ON WINTER WHEAT GRAIN YIELD

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ABSTRACT

In Croatian Baranya region in a 3-year period (2006/2007-2008/2009) 4 different tillage treatments and 3 nitrogen fertilization levels for winter wheat were compared on hipogley soil type. Tillage treatments (TT) for winter wheat were: 1) Conventional tillage (CT), autumn ploughing, 30 cm; 2) Autumn disk harrowing, 10-12 cm (DT); 3) Autumn soil loosening with chisel, 30-35 cm (LT); 4) No-tillage for winter wheat (NT). Seedbed preparation (disk harrowing, vibro-cultivating) was the same for all treatments, except for NT. Nitrogen fertilization levels (NF) for winter wheat were: 120, 150 and 180 kg N ha^{-1}. 2006/2007 and 2008/2009 years were very dry, whilst 2007/2008 was moderately humid. The strongest impact on yield components and grain yield was due climate conditions, followed by tillage treatments and nitrogen fertilization. On 3-year average, only NT recorded significantly lower yields in comparison with CT. Higher NF levels increased yields significantly and the effect was stronger in moderately humid year. Compensatory effect of nitrogen fertilization relating to soil tillage treatments was evident only in 2007/2008. This research indicated that beside of conventional tillage in soil tillage for winter wheat, some technologically simpler, energetically and economically less demanding solutions could be applied.

Key words: conventional tillage, disk harrowing, no-tillage, soil loosening, nitrogen fertilization.

INTRODUCTION

Implementation and acceptance of soil tillage conservation systems, especially no-tillage, is scarce and precluded, but they are constantly increasing worldwide (Derpsch and Friedrich, 2009). Conservation or reduced soil tillage systems are rarely used in Croatia, whereas the main reasons for insufficient and limited adoption are tradition, lack of knowledge of producers, unsatisfactory technical equipment, weak implementation of science, agro ecological reasons, etc (Stošić, 2012). Advantages of conservation systems or no-tillage are numerous, such as better water conservation especially in dry years (Melaj et al., 2003) and better water infiltration, decomposition of organic matter (Birkás and Gyuricza, 2004) decreased soil erosion (Bašić et al., 2004), improvement of biological characteristics (Bottinelli et al., 2010), decreased weed infestation (Kneževič et al., 2003; Ozpinar, 2006), decreased human labour and energetic consumption (Rathke et al., 2007; Nail et al., 2007), enhanced carbon sequestration (Reicosky and Archer, 2007) etc. On the other hand, certain drawbacks are related to appliance of conservation systems, such as, greater soil compaction of deeper soil layers (Stošić, 2012), lower grain protein content (Cociu and Alionte, 2011), greater N_2O emission (Rochette, 2008) and greater source of diseases (Fernandez et al., 2008) and many times lower yields on areas under conservation tillage or no-tillage (Jug et al., 2011; Stošić, 2012) etc. The intention of this study was to determine the possibility of application some simpler, energetically and economically less demanding tillage solution for winter wheat.

MATERIAL AND METHODS

A field trial was managed at Darda site, Baranya region, in north-eastern Croatia (45°37′N and 18°42′E, 83 m elevation). The experiment was carried out over 3-year period (2006/2007, 2007/2008 and 2008/2009) with winter wheat as a stationary two-factorial experiment with randomised and split-plot block design in four replications. The main factor was soil tillage treatment (TT)

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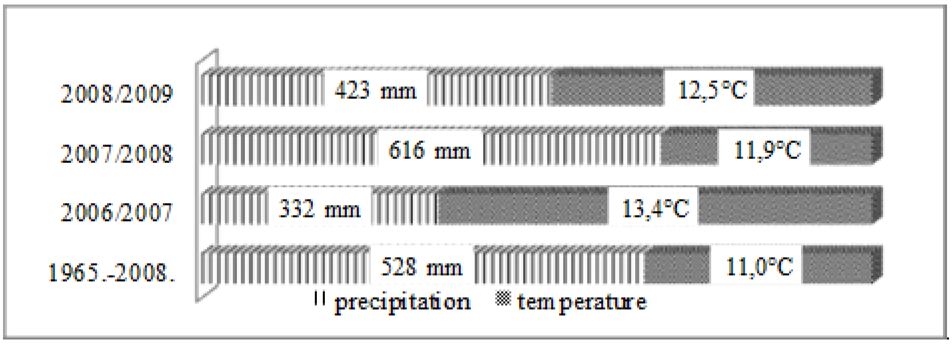
consisting of 4 variants, while the sub factor was N fertilization (NF) divided in 3 levels. Basic tillage plot was 585 m^2, whereas basic N plot was 165 m^2. The field trial was fitted on hypogley soil type ($pH_{(H2O)}$=5.61; $pH_{(KCl)}$=4.52; 0.86 mg kg^{-1} P_2O_5 and 2.42 mg kg^{-1} K_2O (determined by Enger-Riehm Domingo AL method, 1962) and 2.2% organic matter). Winter wheat cultivar Srpanjka was sown at a rate 700 germinating kernels per square meter on 26th, 18th, and 24th October 2006, 2007 and 2008, respectively. Conventional tillage was applied prior to the start of the trial. Potassium and phosphorus fertilization as well as the plant protection from weeds, pests and diseases were uniform for all investigated tillage and fertilization variants. Applied tillage treatments were: 1) Conventional tillage (CT) based on autumn ploughing (30 cm); 2) Autumn disk harrowing (DT); 3) Autumn soil loosening (30 cm) with chisel (LT); 4) No-tillage (NT). Seedbed preparation consisted of disk harrowing for all treatments, except for No-tillage. Nitrogen fertilization (NF) was subfactor and consisted of three levels: 120, 150 and 180 kg N ha^{-1}. The following parameters were determined: winter wheat plant density at emergence (plants m^{-2}, counted in 4 frames with dimension 0.25 m^2, growing stage 1 by Feekes), at heading (ears m^{-2}, growing stage 11 by Feekes), thousand kernel weight, hectolitre mass, grain yield in t ha^{-1} (measured on Schrran portable wheel scale, calculated on 13% grain moisture content). Effect of different soil tillage treatments (TT) and nitrogen fertilization (NF) on winter wheat yield components was examined by ANOVA of the split-plot-plot design, therewith Year (Y) was tested as the main factor, Tillage Treatments (TT) as the sub factor and Nitrogen Fertilization (NF) as the sub-sub factor.

RESULTS

Weather characteristics during of research were very unfavourable in terms of precipitation and temperature regime (Graph 1). Out of three years of research, two were dry, 2006/2007 extremely dry and 2008/2009 dry, while 2007/2008 was favourable, respectively moderately humid.

During of winter wheat vegetation (October - July) 2006/2007 332 mm of precipitation were recorded, which is 196 mm less in comparison to the 40-year average. Also, in 2008/2009 423 mm were recorded, which is 115 mm less than long-term mean. Conversely, 2007/2008 precipitation was 87 mm higher (616 mm) than 40-year average. High average temperatures that occur during of winter season (October - March) were higher in 2006/2007 by 2-6°C and in 2008/9 by 1-3°C than long-term mean. In 2007/2008 average, temperatures in this season were slightly higher, by 1-1.5°C, except of February, which was warmer by 4.2°C than 40-year average. Ultimately, 2006/2007 was extremely dry, 2007/2008 was moderately humid, while 2008/2009 was dry again.



Graph 1. Weather conditions during the investigation from 2006-2009 and long term mean from 1965-2008

1. Plant density at emergence

During of 2006/2007 plant density was realized on average 38%, 50% during of 2007/2008 and 36% during of 2008/2009. Differences for number of plants between years were very significant (F=149.30**;

VC=9.91%). There were no statistical differences on reduced tillage systems in comparison to CT during of 2006/2007 (456 plants m^{-2}) and 2008/2009 (CT=441 plants m^{-2}). In 2007/2008, significantly lower values were recorded only on NT (310 plants m^{-2}) in comparison to CT (363 plants m^{-2}). The impact of NF levels on number of plants was absent in all investigated years.

2. Plant density at heading

The results for this parameter showed very significant influence only for the year (F=22.44**) with relatively weak variation coefficient of 16.90%. Influence of TT (F=1.92, VC=8.75%) was absent and in all investigated years differences between TT were non significant. Relating to the influence of NF, in 2006/2007 significantly higher values were recorded only on NF 180 (699 ears m^{-2}) in comparison to NF 120 (675 ears m^{-2}). During 2007/2008, NF 150 (694 ears m^{-2}) and 180 (723 ears m^{-2}) were significantly higher when compared to NF 120 (660 ears m^{-2}), as well as between NF 180 and 150. In the third year (NF 120=639 ears m^{-2}), significantly higher number of ears were observed on NF 150 (671 ears m^{-2}) and 180 (678 ears m^{-2}).

3. Thousand-kernel weight

The analysis of variance and F-test for this indicator showed that the year had very significant influence (F=293.79**, VC=5.98%), as well as the different TT (F=7.78**) and the levels of NF (F=11.00**). In 2006/2007 significantly lower mass was achieved on NT (29.5 g) compared to CT (34.3 g), whilst in 2007/2008 and 2008/2009 differences were non significant. Relating to NF effect, in 2007/2008, significantly lower mass was achieved by NF 150 (39.6 g) and 180 (39.0 g) in comparison to NF 120 (40.2 g). Similarly, in 2008/2009, significantly lower mass was achieved only by NF 180 (37.5 g).

4. Hectolitre mass

In accordance with F-test for the year, the differences between years were very significant (F=254.22**; VC=0.97), while the influence of TT (F=3.30**) and NF (F=5.13**) was much weaker. Only during of 2006/2007, NT (78.9 kg) gave significantly lower hectolitre mass in comparison to CT (80.8 kg). Regarding to the NF effect, only in 2008/2009 (F=9.67**; VC=0.82%), significantly higher values were recorded on NF 150 (79.0 kg) and 180 (79.3 kg) when compared to NF 120 (78.6 kg).

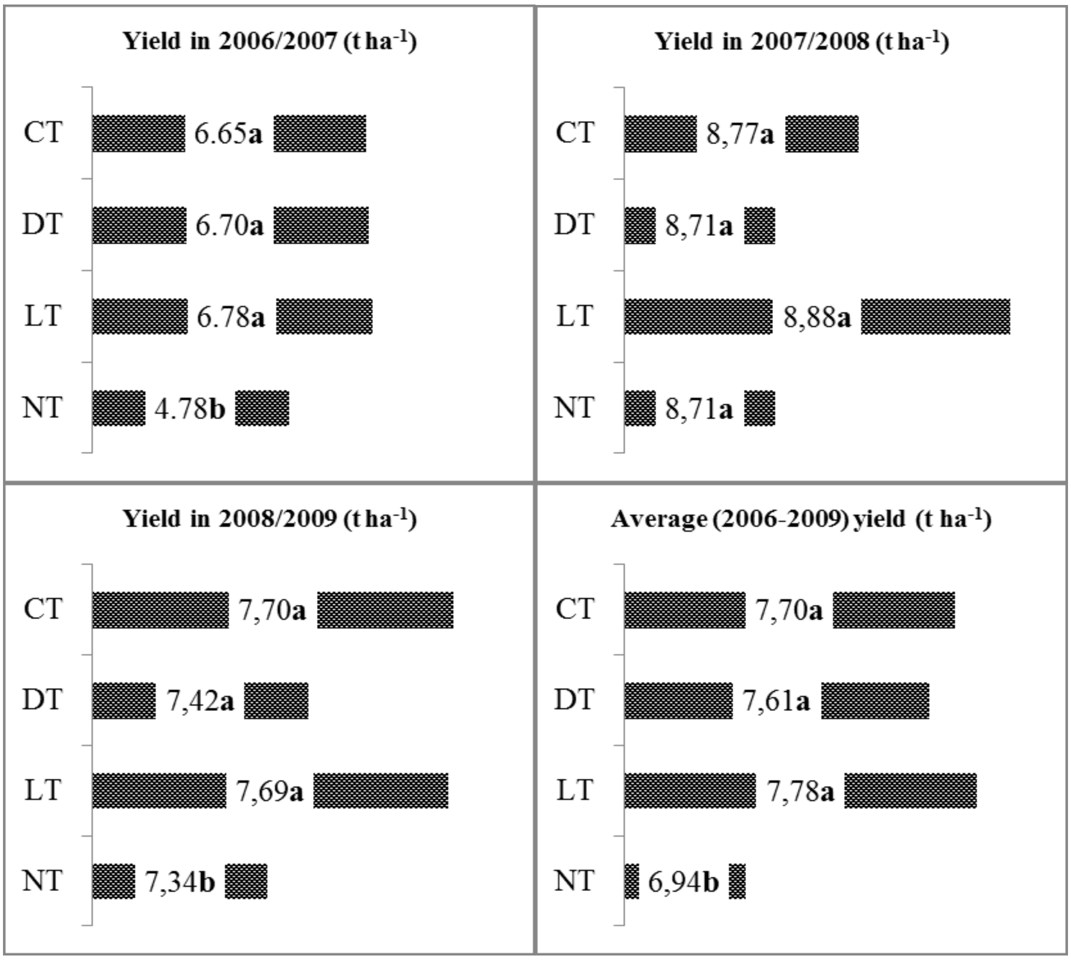
5 Grain yield

On average, the grain yields (Graph 2) were under the highest impact of weather conditions (F=735.97**), followed by NF (F=81.13**) and TT (F=13.18**). The lowest average grain yield was recorded in extremely dry 2006/2007 (6.21 t ha^{-1}). The yields were much higher in moderately wet 2007/2008 (8.75 t ha^{-1}) and somewhat higher in again very dry 2008/2009 (7.54 t ha^{-1}).

Table 1. Yield of winter wheat on different NF levels during the investigation from 2006 to 2009, Darda site (NF 120=120 kg N ha^{-1}, NF 150=150 kg N ha^{-1}. NF 180=180 kg N ha^{-1})

Nitrogen fertilization (NF)	Year (Y)			Mean (NF)
	2006/2007	2007/2008	2008/2009	2006-2009
NF_{120}	5,97**a**	8,21**a**	7,30**a**	7,16**a**
NF_{150}	6,23**b**	8,76**b**	7,44**ab**	7,48**b**
NF_{180}	6,42**b**	9,27**c**	7,87**b**	7,85**c**
Mean (Y)	6,21**a**	8,75**c**	7,54**b**	7,50
0.05	0,23	0,16	0,14	0,11
0.05	0,13			

*values marked with same letter are not different at 0.05 confidence level



Graph 2. Yield of winter wheat on different TT during the investigation from 2006 to 2009, Darda site (CT=mouldboard ploughing; DT=disk harrowing; LT=chiselling+disk harrowing; NT=No-tillage)

The differences between years were significant. Concerning to the influence soil tillage, very significant effect of TT was recorded in 2006/2007 (F=12.91**; VC=6.19%) and 2008/2009 (F=6.30**; VC=7.65%). In the 2006/2007, significantly lower yield was recorded only by NT (-1870 kg ha^{-1}) in comparison to CT (6.65 t ha^{-1}). In the 2008/2009 (CT=7.70 t ha^{-1}), significantly lower yields were obtained by NT (-360 kg ha^{-1}).

Concerning the effect of NF (Graph 2), in 2006/2007 NF 150 and 180 gave significantly higher yields compared to NF 120, while in the 2007/2008 grain yields were significantly higher by every higher NF level (NF_{120}=8.21, NF_{150}=8.76 and NF_{180}=9.27 t ha^{-1}).

DISCUSSION

The presented results are in compliance with numerous authors who accentuated exponentiation or exclusion of positive or negative effects of soil tillage and nitrogen fertilization in correlation with climatic conditions (Phillips and Phillips, 1984; Sprague and Triplett, 1986; Rasmussen, 1999; Melaj et al., 2003; Angas et al., 2006; Várallyay et al., 2010; FAO, 2011). The obtained results showed that, excluding the weather conditions, the strongest influence on the investigated parameters had TT, much less NF and at the end TT × NF interaction. Regarding TT, the results showed the significant influence on all investigated indicators, but only for the TT with stronger tillage reduction. The influence of TT on number of emerged plants was very significant, but on the 3-year average only NT had significantly lower number in comparison to CT. Also, the results showed that on some treatments, mainly with disk harrowing, plant population was higher. Similarly, many authors stated that higher number of emerged plants is to be expected on variants with shallower soil tillage in drier climate

(Stipešević, 1997; Stošić, 2012), due to improved capillary rise of water and better seedbed preparation. Also, very important is the rapid succesion of tillage and sowing in drier conditions, to prevent the soil from drying out (Birkás, 2008). Relating to the influence of TT on number of ears, the effect was absent (Lithourgidis et al., 2006). In connection with thousand-kernel weight, the results showed that the influence of TT was very weak, except in 2006/2007 when NT was significantly lower compared to CT. This is in accordance with some authors who stated that no differences in kernel weight between tillage systems were recorded (Carr et al., 2008; Jug et al., 2011). Regarding to the hectolitre mass, the effect of TT was somewhat stronger than for thousand-kernel weight. In the first year, NT recorded significantly lower hectolitre mass in comparison to CT (Jug et al., 2011). In general, the high evapotranspiration during the growing period and a low rainfall resulted in significant water deficit (Stošić, 2012). Limited crop growth and developtment are direct consequence of water deficit (Halvorson et al., 1999), which is characteristic for this region during the growth period (Žugec, 1984). In connection with influence of TT on the obtained yields, the results showed that only TT with stronger reduction gave significantly lower yields. The reasons for such results lie probably in drought stress and diseases. Namely, increased air temperatures and less than half monthly precipitation during of period October-December 2006 favoured development of *Barley Yellow Dwarf Virus* and *Pyrenophora tritici repentis.* On 3-year average, as well as in extremely dry 2006/2007, yield by NT (-760 kg ha^{-1}) was significantly lower in comparison to CT (7.74 t ha^{-1}). In the dry 2008/2009 the yields on these treatments were also lower, but in moderately humid 2007/2008 the differences between TT were non significant (Torbert et al., 2001; Alvarez and Steinbach, 2009). Regarding to the effect of NF, the results showed sometimes a weak influence on the production indicators. The impact of NF levels on the number of emerged plants was not evident, while at earing stage higher levels of NF realised significantly higher number of ears, what was especially expressed in the moderately humid year (Rasmussen et al., 1997; Lithourgidis et al., 2006). NF affected thousand-kernel weight significantly, but sometimes in decreasing direction. For instance, NF 150 and 180 in 2007/2008 and 2008/2009 realised significantly lower thousand-kernel weight in comparison to NF 120 (Rasmussen et al., 1997). As regards hectolitre mass, higer NF levels resulted, in one out of three years, in significantly higher values of this indicator. This can be related to the fact that, in warmer conditions grain yield is mainly determined by the number of plants at heading, whilst in cooler conditions it is determined by kernel weight (García del Moral et al., 2003). Concerning the NF, the results showed that in extremely dry 2006/2007 NF 150 (+260 kg ha^{-1}) and NF 180 (+450 kg ha^{-1}) gave significantly higher yields in comparison to NF 120 (5.97 t ha^{-1}). In moderately humid 2007/2008, relation was similar, with NF 150 (+550 kg ha^{-1}) and 180 (+1060 kg ha^{-1}), but in dry 2008/2009, it was the case only for NF 180 (+570 kg ha^{-1}). Similar results were obtained in studies of many authors (López-Belido et al., 1998; Torbert et al., 2001; Staggenborg et al., 2003). Compensatory effect of NF in relation to TT was not expressed in extremely dry 2006/2007 and dry 2008/2009, while in the moderately humid 2007/2008 this effect resulted in significant differences. For example, the grain yield by NF 180 at NT (9.19 t ha^{-1}), comparing to NF 120 at CT (8.38 t ha^{-1}), was significantly higher, by 810 kg ha^{-1}. Obviously the results of this research showed that almost all investigated parameters varied, especially the yields, but statistically, not expressed enough for every tillage and fertilization treatment, except for some tillage variant, such as NT and NF 120 fertilization level. Only these treatments mainly resulted in significantly lower values for plant densities, 1000 kernel weight and hectolitre mass and finally for the yields, inspite of evident, but unsatisfactory present compensatory effect of higher NF levels.

This research showed that besides conventional tillage, most investigated treatments could be applied in tillage and fertilization practice for winter wheat, while NT solutions could be pretty risky, but promising. Further investigations are necessary.

CONCLUSIONS

The strongest influence on winter wheat grain yield had the weather conditions, then tillage treatments whilst the influence of nitrogen fertilization was the lowest. Other tillage systems, alongside conventional tillage, can be applied for winter wheat, some of them are technologically simpler, more energy and less economically demanding solutions, ultimately some of them are less and the other more risky.

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