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THE DEPENDENCE OF GRAIN MAIZE YIELD (*ZEA MAYS* L.) FROM DIFFERENT SOIL TILLAGE AND METEOROLOGICAL CONDITIONS

ZÁVISLOSŤ ÚRODY ZRNA KUKURICE SIATEJ (*ZEA MAYS* L.) OD ROZDIELNYCH SPÔSOBOV OBRÁBANIA PÔDY A POVETERNOSTNÝCH PODMIENOK

ANDREJ HNÁT

Plant Production Research Center Piešťany − Research Institute of Agroecology Michalovce
Centrum výskumu rastlinnej výroby Piešťany − Výskumný ústav agroekológie Michalovce

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Between 2003 and 2007 the effect of three soil tillage systems and the sum of precipitation and average air temperature to grain maize yield (*Zea mays* L.) was observed. Grain maize was cultivated in a stationary crop rotation system as follows: winter wheat – grain maize, hybrid DK 440 (FAO 350) – spring barley – soya bean. Experiments were carried out in the East Slovak Lowland area of Gleyic Fluvisol. Three soil tillage technologies were examined: ct – conventional tillage, i.e. current method with agrotechnics operations as follows: skimming, autumn ploughing, soil cultivation before grain maize sowing (smoothing, harrowing); mt – minimum tillage, i.e. only skimming to a depth of 0.10 m; nt – no-tillage technology, i.e. without any cultivation from the harvest of forecrop until the harvest of grain maize. These tillage systems took place on all field crops during the whole experimental period. Seeder Kinze 2000 was used in all tillage systems.

The area of soil tillage variant was 414 m^2 (18 × 23 m). Grain maize was harvested manually in phases of full ripeness from an area of 32.2 m^2 (1.4 × 23 m). Obtained results of grain maize yields were tested by statistical methods. For the determination of dependence between grain maize yield and meteorological factors the linear model of regression analysis was used.

In the observed period grain maize yield was determined from 7.986 to 14.260 t ha^{-1} (variability 79%). Experimental year and soil tillage system had statistically significant effects to grain maize yield. The influence of the experimental year on the yield was greater than the effect of soil tillage. From the point of view of soil tillage statistically significant differences for yields of grain maize were determined. For conventional tillage the highest average yield – 11.578 t ha^{-1} – was ascertained, at minimum tillage the yield was lower (10.705 t ha^{-1}) and the lowest yield (10.119 t ha^{-1}) for no-tillage system was determined. Between all experimental years mutually, with the exception of the years 2003–2006 and 2005–2007, significant differences for grain yield caused with high variability of meteorological factors were determined. For conventional tillage and no-tillage systems for total sum of precipitation in June and July and grain maize yield high statistically significant direct dependence ($r = 0.88^+$) were determined. The dependence of the total sum of precipitation in the months of August and September ($r = -0.91^+$, respectively $r = -0.93^+$) and also in months August, September and October ($r = -0.95^+$, respectively $r = -0.93^+$) on grain maize yield was indirect, but statistically significant.

Key words: *Zea mays*, soil tillage, sum of precipitation, air temperature, grain yield

The husbandry system on soil together with the course of weather conditions effect soil properties changes. The tillage system of soil has a very important role. From the point of view of energy and economy, soil tillage is the most exacting part of the production process.

Worldwide, mainly for these reasons so-called protective systems for soil tillage are used. It is established at various degrees of conventional tillage at reduced ploughing, i.e reversal of the top layer of soil and its compensation with various forms of minimum (reduce) tillage whereby post-harvest residues are kept in the

Ing. Andrej Hnát, Plant Production Research Center Piešťany − Research Institute of Agroecology, 071 01 Michalovce, Špitálska 1273, Slovak Republic. E-mail: hnat@scpv-ua.sk

field. The extreme boundary of minimisation of tillage is so-called no-tillage technologies – direct sowing without ploughing. Intermediate stages between conventional soil tillage and no-tillage systems are various sorts of surface preparation of soil. The aim of these systems is decreasing of inputs to production process, but adequately qualitative prepare of seed-bed.

The soil protective technologies are frequently studied. The various aspects of minimised soil tillage published for example López-Fando and Almendros (1995), Suškevič (1995), Etana et al. (1999), Čupa (2000), Hao et al. (2001), Knežević et al. (2003), Matula (2003), Stipešević and Kladivko (2005). The soil protective technologies in the conditions of the Slovak Republic studied by Miština et al. (1993), Žák et al. (2002), Hnát et al. (2003), Kováč et al. (2005), Kotorová and Hnát (2005), Kotorová (2007). The effect of climatic and weather conditions of the environment on yield creation of grain maize analysed Petr et al. (1980), Pospišil (1995), Žembery et al. (2005), Samuhel et al. (2007) and others.

The soil protective technologies, that mainly direct sowing without ploughing, are very frequently used for cereal crop production, especially for winter wheat and grain maize. The several factors that inhibit to extend these technologies also work for other crops. Belonging to for example, the lower yields in comparison with conventional tillage, but also insufficient knowledge basin about the effect of these systems on biological, physical and chemical properties of the soil environment.

The aim of this paper is to document the effect of three different systems of soil tillage and meteorological conditions on grain maize yield cultivated on heavy gleyic soil in the agro-ecological specific area of the East Slovak Lowland.

T a b l e 1

Weather conditions during experimental season – average air temperature [°C]

Month	n30	2003	± to n30	2004	± to n30	2005	± to n30	2006	± to n30	2007	± to n30
I.	−3.3	−3.2	+0.1	-3.7	-0.4	−1.6	+1.7	-4.7	−1.4	2.4	+5.7
II.	−1.0	−3.5	−2.5	-0.8	+0.2	−3.4	−2.4	−2.6	−1.6	2.8	+3.8
III.	3.5	3.0	−0.5	5.0	+1.5	2.3	−1.2	2.3	−1.2	8.2	+4.7
IV.	9.7	9.5	−0.2	10.7	+1.0	11.0	+1.3	11.3	+1.6	11.2	+1.5
V.	14.6	18.5	+3.9	13.7	−0.9	15.5	+0.9	14.8	+0.2	17.5	+2.9
VI.	18.2	20.3	+2.1	18.2	0.0	18.1	−0.1	18.8	+0.6	20.7	+2.5
VII.	19.6	21.3	+1.7	20.3	+0.7	20.5	+0.9	22.5	+2.9	22.5	+2.9
VIII.	19.0	21.7	+2.7	19.6	+0.6	19.2	+0.2	18.8	−0.2	21.7	+2.7
IX.	14.8	14.5	−0.3	14.0	−0.8	15.8	+1.0	16.3	+1.5	13.6	−1.2
X.	9.1	7.0	−2.1	10.5	+1.4	10.0	+0.9	10.3	+1.2	9.2	+0.1
XI.	4.0	5.5	+1.5	4.6	+0.6	3.1	−0.9	5.4	+1.4	2.5	−1.5
XII.	−0.7	−0.7	0.0	0.2	+0.9	−0.5	+0.2	2.2	+2.9	−0.8	−0.1
$\bar{x}$ I.–XII.	8.9	9.5	+0.6	9.4	+0.5	9.2	+0.3	9.6	+0.7	11.0	+2.1
$\bar{x}$ IV.–IX.	16.0	17.6	+1.6	16.1	+0.1	16.7	+0.7	17.1	+1.1	17.9	+1.9
$\bar{x}$ IV.–IX./n30, [%]	−	−	110	−	101	−	104	−	107	−	112

$\bar{x}$ I.–XII. – average for year
$\bar{x}$ IV.–IX.– average for vegetation period
$\bar{x}$ IV.–IX/n30, % – evaluation to long-time normal for vegetation period, %

n30 − long-time (30-years) normal
± to n30 − evaluation to long-time normal n30

MATERIAL AND METHOD

From 2003 to 2007 at the experimental place Milhostov of the Plant Production Research Center – Research Institute of Agroecology Michalovce a field experiment was carried out on heavy Gleyic Fluvisol (FM_G) in the maize-growing region. The grain maize hybrid DK 440 (FAO 350) was tested in a field experiment.

Gleyic Fluvisol is characterised as a clay-loamy soil, heavy soil with average content of clay elements higher than 53%. This soil has a weak pervious in whole profile. The topsoil has a lump aggregate structure with a high binding ability. The coherent layer of grey clay is usually to a depth of 0.8 m. The high content of clay particles in the profile has a significant effect on the agronomic properties in these soils.

The experimental place has an altitude of 101 m and it belongs in a warm, very dry, lowland and continental agro-climatic region. By Samuhel et al. (2007) on this place the main vegetation season with air temperature higher than 10°C starts 17.04., and it ends after 178 days, i.e. 11.10. The sum of temperatures achieved 2 944°C and that temperature requirements of tested hybrid were protected. The meteorological conditions of the experimental place are shown in Table 1 and 2.

The grain maize was cultivated in 4-plots, a crop rotation as follows: winter wheat – grain maize – spring barley – soybean. Three soil tillage systems were compared with operations as follows: conventional tillage (ct) – sharing, treatment of sharing, autumn ploughing, soil prepare before sowing (smoothing, harrowing); minimum tillage (mt) – sharing, treatment of sharing, before sowing cultivation by share plough in depth 0.10 m; direct sowing without ploughing (nt) – without any cultivation from harvest of forecrop to harvest of grain maize. These systems of soil tillage were applied for all crops in crop rotation during the whole experi-

Table 2

Weather conditions during experimental season – sum of precipitation [mm]

Month	n30	2003	± to n30	2004	± to n30	2005	± to n30	2006	± to n30	2007	± to n30
I.	32	23	−9	26	-6	15	−17	13	−19	40	+8
II.	28	17	−11	50	+22	42	+14	41	+13	40	+12
III.	27	13	−14	21	-6	7	−20	48	+21	18	−9
IV.	39	19	−20	35	-4	65	+26	49	+10	6	−33
V.	53	32	−21	84	+31	105	+52	83	+30	38	−15
VI.	78	57	−21	73	-5	61	−17	96	+18	72	−6
VII.	76	90	+24	148	+72	52	−24	18	−58	36	−40
VIII.	63	34	-29	70	+7	159	+96	151	+88	29	−34
IX.	41	82	+41	48	+7	42	+1	5	−36	147	+106
X.	39	69	+30	41	+2	17	−22	23	−16	62	+23
XI.	43	31	−12	35	−8	13	−20	16	−27	26	−17
XII.	41	22	−19	15	−26	57	−16	13	−28	29	−12
∑ I.–XII.	559	489	−70	645	+87	635	+76	556	-3	543	−16
∑ IV.–IX.	348	314	−34	458	+110	484	+136	402	+54	328	−20
IV.–IX./n30, [%]	–	–	90	–	132	–	139	–	116	–	94

∑ I. – XII. – sum for year
∑ IV. – IX. – sum for vegetation period
∑ IV.–IX/n30, % – evaluation to long-time normal for vegetation period, %

n30 − long-time (30-years) normal,
± to n30 − evaluation to long-time normal n30

mental season. At all systems of soil tillage the sowing machine for precise seed (type of sowing machine Kinze 2000) was used.

In spring, under grain maize rates 90 kg ha^{-1} N, 30 kg ha^{-1} P and 90 kg ha^{-1} K one-component and two-components mineral fertilisers were applied. The nitrogen was used as ammonium sulphate (20.5% N), ammonium nitrate (27.5% N) and ammophos (12.0% N). The phosphorus was used as triple superphosphate (47.0% P) and ammophos (49.0% P). The potassium as potassium chloride (59.8%) was used. The fertilizers had large species and formulating spectrum and that it was applied by hand. The area of experimental variant was 414 m^2 (18 × 23 m). Each variant of soil tillage was replicated four times. The grain maize was manually harvested from an area 32.2 m^2 (1.4 × 23 m) in the full ripeness stage. With 86% dry matter the grain yields are presented.

Obtained data was tested by mathematical-statistical methods, from which analysis of variance, LSD-multiple test and regression analysis were used (Grofik and Fľak 1990). The analysis of variance was made by programme Statgraphics version 5.0 and the regression analysis by programme Statgraphics version 2.1. For determination of dependence of the grain maize yield on sum of precipitation and air temperature the linear model of regression analysis (y = a + bx) was used. For this dependence the correlation coefficients (r) were calculated individually for sum of precipitation and for average air temperature for January to October. The coefficients were determined also for cumulative months: 1–2, 1–3, 1–4, 1–5, 1–6, 1–7, 1–8, 1–9, 1–10; 2–3, 2–4, 2–5, 2–6, 2–7, 2–8, 2–9, 2–10; 3–4, 3–5, 3–6, 3–7, 3–8, 3–9, 3–10 and analogously for the combination of months 4 till 10 (where 1–2: January and February – sum of precipitation for these months, respectively average of air temperature for these months; similarly 1–3: January till March – sum of precipitation for these months, respectively average of air temperature etc.).

RESULTS AND DISCUSSION

The yield of grain maize is a most important production parameter, which is significantly effected by soil tillage and course of meteorological conditions of the production year.

Between the experimental years 2003 and 2007 in dependence on used tillage system of soil (Table 3) the grain maize yield was determined from 7.986 t ha^{-1} to 14.260 t ha^{-1} (variability 79%). On average of the experimental years the highest yield was obtained at conventional tillage of soil – 11.578 t ha^{-1}, lower yield was determined at minimum tillage of soil – 10.705 t ha^{-1} (less about 8.2%) and the lowest yield was found out for no-tillage variant – 10.119 t ha^{-1} (less about 14.4%). From the point of view of trend yield quantity such order of tillage variants (ct > mt > nt) was reached in years 2004, 2005 and 2007. In year 2003 the order of tillage variants was as follows: ct > nt > mt and in year 2006 it was mt > ct > nt. This ambiguity of trend could be due to the course of weather conditions of the cultivated year.

From multifactor analysis of variance for grain maize yield (Table 4) statistically significant effects of experimental year and soil tillage system was observed. The effect of the experimental year was higher than the effect of soil tillage. These results corresponded with data published by Knežević et al. (2003), which in conditions in Croatia found a significant effect of cultivated year and soil tillage system on grain maize yield. But in comparison with ploughing technology at reduce soil systems the yield of grain maize was lower by about 10–22%. Also Žák et al. (2002) published, that at integrated system of grain maize cultivation (no-till system) in comparison to low-input system (conventional tillage) yields of grain maize were lower by about 1.2 till 28.9% (in average about 17.2%).

From the multiple tests of the comparison of grain yields (Table 5) it becomes clear, that from the point of view of soil tillage statistically significant differences of grain yields between all three examined tillage systems were determined and yields was decrease as follows: conventional tillage – minimum tillage – no-tillage.

From this comparison also resulted, that between all experimental years mutually, with the exception of 2003–2006 and 2005–2007, highly significant differences between grain yields were noted. The order of years by grain yield (from maximum to minimum) was as follows: 2004, 2006, 2003, 2007 and 2005.

From data shown in Table 1 and 2 results showed the variability of meteorological conditions of experimental years (sum of precipitation and average air temperature) in comparison to the long-time normal.

The vegetation seasons of experimental years from point of view of air temperature were valued by Ivančo et al. (2004) and were compared to the long-time normal. These average air temperatures were higher than the long-time normal and reached 101–112% from this normal. The vegetation season with this range is valued as normal (normal vegetation is defined by range 90–110% of long-time normal) till warm vegetation season (range 111–120% of long-time normal), that of adjacent categories. From point of the view of sum of precipitation, at the same valuation, between experimental years determined differences were higher than at air temperature. Scatter of values in comparison to long-time normal was from 90% to 139% and vegetation seasons is possible to valued as normal (90–110%) till very humid (121–140%). The large interval of values covered till three categories of vegetation season – normal, humid, very humid (till to boundary of extremely humid).

It is known, that the meteorological conditions – sum of precipitation and air temperature – has an influence on the growth and development of plants not only during individual months, but its effect on plants is cumulative (Petr et al. 1980; Pospišil et al. 1995; Žembery et al. 2005). The degree of this significance is conditioned mainly with extreme values of temperature and rainfall course. From the point of view of the effect of the sum of precipitation and air temperature on grain maize yield in dependence from used tillage systems had a statistically significant effect ($P < 0.05$) on the sum of precipitation. This fact was legal only for a specific period. The statistically significant dependences between grain maize yield and average air temperature wasn't determined. But for conventional

T a b l e 3

Grain maize yield [t ha^{-1}] in dependence from soil tillage technology

Soil tillage	Experimental years					$\bar{x}$Y
	2003	2004	2005	2006	2007	
ct	12.750	14.260	9.812	11.681	9.388	11.578
mt	9.760	14.030	8.832	11.863	9.042	10.705
nt	11.150	12.860	7.986	10.312	8.289	10.119
$\bar{x}$T	11.220	13.717	8.877	11.285	8.906	10.801
ct:mt [%]	130.6	101.6	111.1	98.5	103.8	108.2
ct:nt [%]	114.3	110.9	122.9	113.3	113.3	114.4
mt:nt [%]	87.5	109.1	110.6	115.0	109.1	105.8

Y – average for experimental years, T – average for soil tillage, ct – conventional tillage, mt – minimum tillage, nt – no-tillage

T a b l e 4

Analysis of variance for grain maize yield

Source of variation	d.f.	F	P	Order
Soil tillage	4	32.287	++	2.
Experimental year	2	145.630	++	1.
Residual	50			
Total	59			

d. f. – degrees of freedom, F – calculated F, P – effect of factor significant at the level $\alpha = 0.01$

T a b l e 5

Multiplied LSD-test of grain maize yield comparing

Observed factor		Yield mean	Homogenous groups			Contrast	Difference	$LSD_{0.05}$
Soil tillage	nt	10.119	×			ct−mt	0.87280	0.48933
	mt	10.705		×		ct−nt	1.45880	0.48933
	ct	11.578			×	mt−nt	0.58600	0.48933
Experimental year	2005	8.877	×			2003−2004	–2.49667	0.63172
	2007	8.906	×			2003−2005	2.34333	0.63172
	2003	11.220		×		2003−2006	–0.06533	0.63172
	2006	11.285		×		2003−2007	2.31367	0.63172
	2004	13.717			×	2004−2005	4.84000	0.63172
						2004−2006	2.43133	0.63172
						2004−2007	4.81033	0.63172
						2005−2006	–2.40867	0.63172
						2005−2007	–0.02967	0.63172
						2006−2007	2.37900	0.63172

nt − no-tillage, mt − minimum tillage, ct − conventional tillage
LSD – least significant difference

tillage variant strong dependence between grain yield and summary of rainfall of June and July ($r = 0.88^{+}$, $b = 0.037681$), August and September ($r = –0.91^{+}$, $b = –0.050056$) and together August, September and October ($r = –0.95^{+}$, $b = –0.060770$) were discovered. Similarly also for no-tillage variant were determined strong dependences between grain yield and summary of rainfall in June and July ($r = 0.88^{+}$, $b = 0.037663$), August and September ($r = –0.93^{+}$, $b = –0.051144$) and together August, September and October ($r = –0.93^{+}$, $b = –0.059557$). The strong direct dependence between grain yield and summary rainfall of June and July at higher noted soil systems correspond with the knowledge, that middle late hybrids, to which belongs also our experimental hybrid, in phase of intensive growth and development of generative organs the grain maize need sufficiency of water in soil (Žembery et al. 2005). On the other hand strong indirect dependences indicate a negative effect of high summary rainfall in August and September, therefore at the end of the vegetation period of grain maize, on creation of grain maize yield.

At the minimum technologies the soil properties are changed and from it may result a decreasing or variation of grain maize yields. For example Matula (2003) ascertained that reduced soil tillage and no-tillage changes of hydrophysical properties of soil, mainly three- till six-multiple decreases the saturated hydraulic conductivity of topsoil. This decrease can cause an increase of subsoil density, increase of surface runoff, danger of erosion and effect on yields of plants. Also Kováč et al. (2005) determined a higher soil moisture under grain maize stand at conventional tillage than at soil protective systems (reduce tillage, mulching, no-tillage). On the other hand Stipešević and Kladivko (2005) published that in treatments in Indiana (USA) conditions of young plants of maize there was better growth with no-tillage technology in comparison with double disking. From results presented here influenced importance of soil protective technologies in conditions of heavy soils of the East Slovak Lowland. The research of these technologies is needed to point to broader knowledge of causality of achieved yields of grain maize and factors which their conditional.

CONCLUSION

From results obtained between 2003 and 2007 about the effect of various soil tillage technologies and weather conditions – sum of precipitation and air temperature – on grain maize yields it is possible to formulate conclusions as follows:

During the observed term the grain maize yield varied from 7.978 to 14.260 t ha^{-1} (variability 79%) and it was statistically significant effected by experimental year and used system of soil tillage. The effect of experimental year was higher than the effect of soil tillage.

From the point of view of soil tillage statistically significant differences of grain maize yield were determined, when the highest average yield was ascertained at conventional tillage – 11.578 t ha^{-1}, lower at minimum tillage – 10.705 t ha^{-1} (less about 8.2%) and the lowest yield was at no-tillage – 10.119 t ha^{-1} (less about 14.4%).

Between all experimental years mutually, with the exception of 2003–2006 and 2005–2007, it was noted that highly significant differences between grain yields caused with variability of weather conditions. The order of years by grain yield (from maximum to minimum) was as follows: 2004, 2006, 2003, 2007 and 2005.

At conventional tillage and no-tillage strong dependence between grain yield and summary of rainfall of June and July ($r = 0.88^+$), August and September ($r = –0.91^+$, respectively $r = –0.93^+$) and together August, September and October ($r = –0.95^+$, respectively $r = –0.93^+$) were found out by the regression analysis method. From the presented dependences result positive, respectively negative effect of soil water storage on growth-development stages of grain maize and further on grain yield.

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SÚHRN

V rokoch 2003–2007 sme v stacionárnej sústave striedania plodín pšenica letná f. ozimná − kukurica siata, hybrid DK 440 (FAO 350), − jačmeň siaty jarný − sója fazuľová na fluvizemi glejovej (FM_G) v oblasti Východoslovenskej nížiny sledovali vplyv troch spôsobov obrábania pôdy a úhrnov zrážok a teplôt vzduchu na úrodu zrna kukurice siatej (*Zea mays* L.). Obrábanie pôdy predstavovali: konvenčná agrotechnika (ct) − podmietka, ošetrenie podmietky, jesenná orba, predsejbová príprava pôdy (smykovanie, bránenie); minimalizačná agrotechnika (mt) − podmietka, ošetrenie podmietky, kultivácia radličkovým podmietačom pred sejbou do hĺbky 100 mm; priama sejba do nepripravenej pôdy (nt) − bez akejkoľvek kultivácie od zberu predplodiny po zber kukurice. Uvedené spôsoby obrábania pôdy sme použili pri všetkých plodinách počas celého pokusného obdobia. Pri všetkých spôsoboch obrábania pôdy sme kukuricu siali sejačkou na presný výsev (Kinze 2000).

Každý variant obrábania pôdy s plochou 414 m^2 (18 × 23 m) sme založili v štyroch opakovaniach. Kukuricu sme zberali ručne vo fáze plnej zrelosti z plochy 32,2 m^2 (1,4 × 23 m). Získané výsledky úrody zrna sme spracovali matematicko-štatistickými metódami − analýzou rozptylu, LSD-testom a regresnou analýzou. Pre zistenie závislosti úrody zrna kukurice od úhrnu zrážok a teploty vzduchu sme použili lineárny model regresnej analýzy y = a + bx. Korelačné koeficienty (r) sme vypočítali pre túto závislosť osobitne od úhrnu zrážok a osobitne od priemernej teploty vzduchu za mesiace január až október, ale aj za kumulované mesiace.

V sledovanom období sa úroda zrna kukurice pohybovala od 7,986 do 14,260 t.ha^{-1} (variabilita 79 %) a bola štatisticky vysoko preukazne ovplyvnená pokusným rokom a spôsobom obrábania pôdy. Vplyv pokusného roku bol pritom väčší ako vplyv spôsobu obrábania pôdy. Z pohľadu obrábania pôdy medzi všetkými skúšanými spôsobmi sme zistili štatisticky vysoko preukazné rozdiely v úrode zrna s najvyššou priemernou úrodou pri konvenčnom obrábaní – 11,578 t.ha^{-1}, nižšou pri minimalizačnom obrábaní 10,705 t.ha^{-1} (menej o 8,2 %) a najnižšou pri priamej sejbe do neobrobenej pôdy – 10,119 t.ha^{-1} (menej o 14,4 %). Medzi pokusnými rokmi navzájom, okrem dvojice rokov 2003–2006 a 2005–2007, sme zaznamenali vysoko preukazné rozdiely v úrode zrna zapríčinené vysokou premenlivosťou poveternostných podmienok. Regresnou analýzou sme pri konvenčnej agrotechnike a priamej sejbe do neobrobenej pôdy zistili štatisticky preukaznú závislosť medzi sumárnym úhrnom zrážok v mesiacoch jún a júl (r = 0,88$^+$) a štatisticky preukaznú nepriamu závislosť medzi sumárnym úhrnom zrážok v mesiacoch august a september (r = –0,91$^+$, resp. r = –0,93$^+$), a tiež sumárnym úhrnom zrážok v mesiacoch august, september a október (r = –0,95$^+$, resp. r = –0,93$^+$) na úrodu zrna kukurice.

Kľúčové slová: *Zea mays* L., obrábanie pôdy, úhrn zrážok, teplota vzduchu, úroda zrna