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Influence of tied ridging technology on the rate of surface runoff and erosion in potato cultivation

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Abstract. Water management and securing good condition of soil is becoming an important factor in agriculture one of the reasons being adaptation to the increasingly frequent extremes in weather. Tied ridging technology enables to reduce significantly the loss of water and soil from arable land. The effect of a tied ridger mounted on 2-row planter and effect of 6-row tied ridger on basin renewal was tested in potato cultivation on plots of land with length of 10 m. During entire season lasting 135 days the technology helped achieve 78% of efficiency in reduction of surface water runoff and 88% of efficiency in case of soil loss. In the case of furrows with only tied ridging the water retained represented additional 15% of total water from rainfall (37.5 mm of 250 mm) over untreated furrows. In the case of basins formed in furrows with wheel trails the water retained represented 15% of total water from rainfalls in the trail. This water retained on the land would have otherwise flown off and would not have been utilized without this technology. The renewal of dams after 1/3 of the season increased significantly the efficiency of this technology. The technology of tied ridging significantly contributes to sustainable agriculture management.

Key words: furrow damming, basin tillage, soil protection, water runoff, trail.

INTRODUCTION

At the present time, potato cultivation in the Czech Republic is an increasingly marginal issue for many companies and this is so even in regions with large potato cultivation areas such as the Vysočina region (No. of NUTS3 – CZ063, mean height 500 m a.m.s.l.). In order to reduce the very high costs arising in potato cultivation, it is important to maintain the best possible quality of soil.

Potatoes together with maize and sugar beet belong to wide row crops. Owing to their cultivation method, wide row crops are more prone to erosion compared to grains (Hůla et al., 2010).

By implementation of anti-erosion measures it is possible to reduce erosion to an acceptable extent which minimizes its harmful effects on principal environmental functions of soil and its production potential. Anti-erosion measures, which can be applied easily, are some agrotechnical measures (Javůrek et al., 2012; Hůla et al., 2016; Kovář et al., 2016).

One of suitable technologies for erosion reduction in wide row crops is tied ridging (Munodawafa, 2012). Tied ridging is a measure with lower cost and minimum impact on traditional cultivation procedure preserving the crop yield without increased input of plant protection agents (Billen & Aurbacher, 2007).

Agriculture equipment for tied ridging creates dams in furrows between ridges which form retention spaces for water. Commercially available devices for anti-erosion protection are relatively few and usually do not treat trail furrows left by the tractor wheels. These furrows add up to as much as 2/3 of area in potato cultivation. In the project of the Technology Agency of the Czech Republic (TACR), No. TA 02020123 anti-erosion devices were developed (Fig. 1). They were a tied ridger mounted on a two-row planter with the aim to merge the technology of planting and tied ridging into one working operation and an anti-erosion device for renewal of furrow dams (Vacek et al., 2015; Mayer et al., 2016). In 2016, trials were established with the aim to evaluate agrotechnical measures carried out in both types of furrows and their effect on erosion and surface runoff of water during potato cultivation.

MATERIALS AND METHODS

The field trials with potato cultivation took place on a field with sandy-loam soil (7% clay, 21.5% silt, 71.5% sand) with the slope of 5°. Stone windrowing was carried out before potato planting. The trial was founded with the aim to develop and deepen the knowledge about anti-erosion technology of tied ridging in connection with stone windrowing. Two-row planter with additional fertilization (RBM-2HP production year 1997, empty weight 610 kg, full weight 1,610 kg, Reekie, Algarkirk, UK) formed dams (0.1 m width) in the furrows creating basins between them. The basins had the following dimensions 0.4 m length, 0.25 m width and average volume 1.5–2 liters. Date of planting: 9.5. The renewal of dams by the 6-rows anti-erosion tied ridger (HEP-7 production year 2015, weight 800 kg, KOVO NOVAK, Citonice, Czech Republic, www.kovonovak.cz) took place on 23.6, which was 14 days after plant emergence (Fig. 4). This renewal can be carried out until the potato plants reach 0.3–0.4 m. Dimensions of reservoirs were the same as at the beginning. The tractor used was Zetor Forterra 125 with output of 95 kW.

Figure 1. Reekie 2-rows planter with tied ridging adapter and KOVO NOVAK 6-rows tied ridger.

On the trial field (N 49°38‘16“, E 15°29‘20“, 450 m a.m.s.l.) 4 variants of trial (F = Furrow, TF = trail furrow, RF = ridging furrow, TRF = trail ridging furrow) were established on 10 m long strips. Distance between ridges in F and RF was 0.75 m and in TF and TRF it was 1.05 m (Fig. 2).

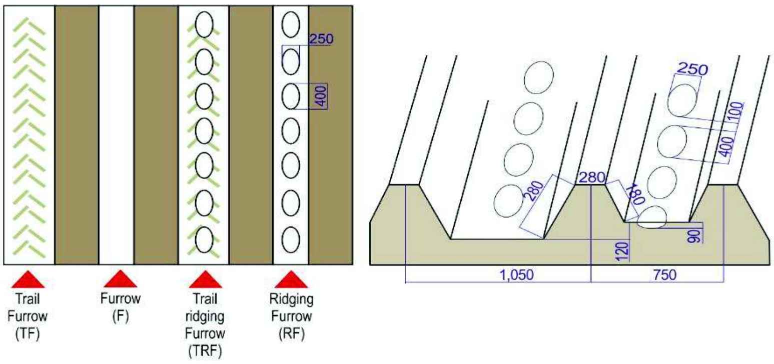

Figure 2. Layout and dimensions (mm) of variants and basins.

Each variant was established in 3 replicates. The rainfalls were recorded by a rain collector with the resolution of 0.3 mm. Volume of the basins was measured by vessel method in 10 replicates and on 8 dates. The water runoff from rainfalls was led to collection vessels separately for each variant by collectors (Fig. 3) and collection was carried out on 12 dates during the season (Fig. 4). By drying the samples of runoff liquid, the values of total soil loss from individual variants were obtained. The last term of runoff collection was carried out on 19.9., when the potato shoots were also removed. Harvest took place on 27.9.2016. The balance of runoff was calculated from the test areas. For the variant with tied ridging and for the variant without tied ridging the area was 54 m^2. Trail variants had the area of 31.5 m^2 (3 x 10.5 m^2) and non-trail variants 23.5 m^2 (3 x 7.5 m^2).

For statistical processing the software Statistica 12 was used employing one-way ANOVA Tukey HSD test.

Figure 3. Collectors for sampling and tied ridging in furrows.

RESULTS AND DISCUSSION

The volume of rainfalls for the whole period of potato cultivation (135 days from planting to shoot removal) was 250 mm m^{-2}. carried out in the first 45 days up to the date of dam renewal there was recorded 75 mm of rainfalls, which represented 30% of total rainfall for the season of potato cultivation. During those 45 days from planting there was recorded 13 out of 35 rainfall events. Eroded soil, owing to the greater rainfalls, especially with higher intensity (Fig. 4, Table 1), deposited in basins and reduced their retention volume (Fig. 5). Therefore, on 23.6. the renewal of dams was carried out by anti-erosion device in order to increase again the volume of basins. Reduction of reservoir volume was more significant in the case of variant with trail (TRF), 50% in comparison with 30% in case of RF.

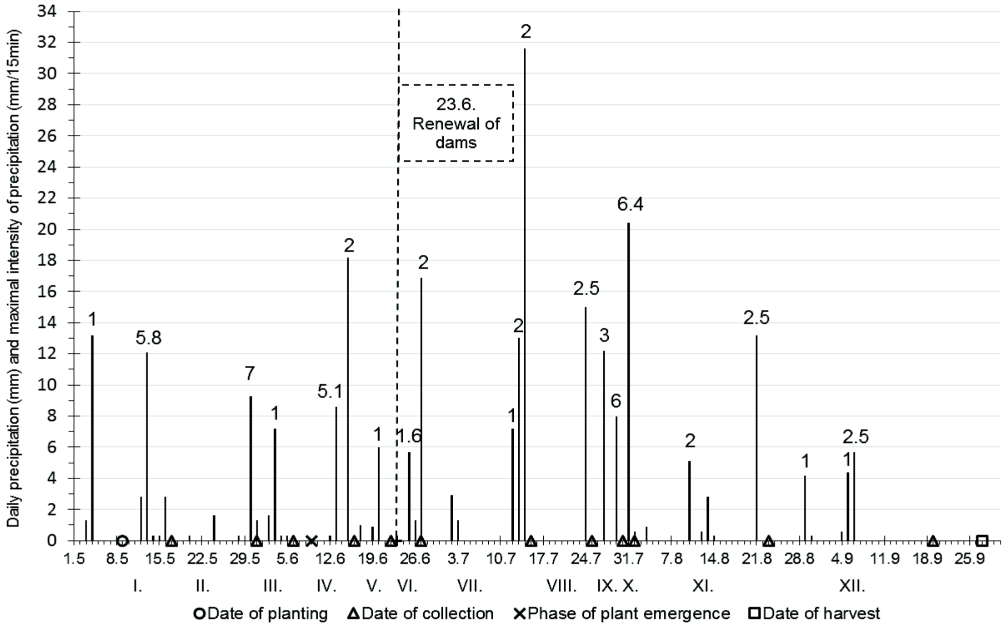

Figure 4. Time series of total precipitations, intensity of precipitation and date of collection.

Table 1. Precipitations in individual periods of collection

Periods of sampling	9.5.–16.5.	17.5.–30.5.	31.5.–5.6.	6.6.–15.6.	16.6.–21.6.	22.6.–27.6.	28.6.–14.7.	15.7.–24.7.	25.7.–29.7.	30.7.–31.7.	1.8.–22.8.	23.8.–19.9.
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Total precipitation (mm m^{-2})	18.3	11.5	10.7	27.1	7.9	23.9	56.0	15.0	20.2	20.4	23.5	15.2
Max daily precipitation (mm)	12.1	9.3	7.2	18.2	6.0	16.9	31.6	15.0	12.2	20.4	13.2	5.7
Max intensity of precitipation (mm 15 min^{-1})	5.8	7.0	1.0	5.1	1.0	2.0	2.0	2.5	6.0	6.4	2.5	2.5

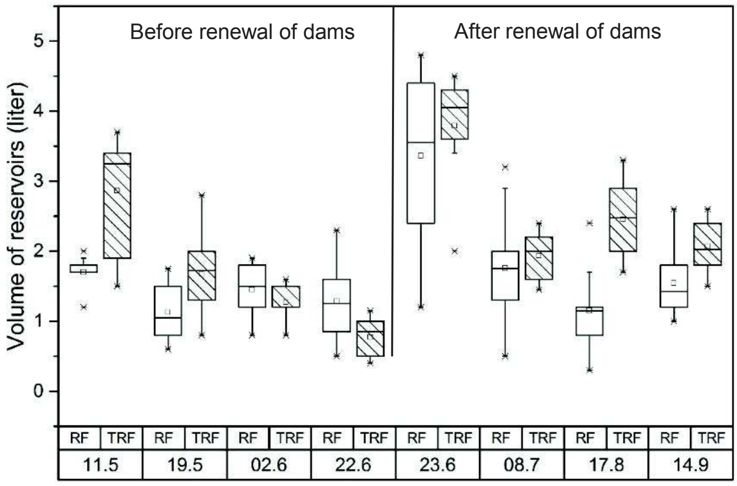

Figure 5. Reduction of volume of reservoirs of individual variants in time.

The volume of basins was higher in early days after the planting and even more notably after the dam renewal. In both cases the higher volume was caused by loosening of surface. The volume stabilized gradually and in 1–2 weeks it was 1.5–2 L. The filling of basins by eroded fine soil was less significant after their renewal on 23.6. This very likely relates to the coverage of sloping sides of ridges by potato shoots. The phase of shoot emergence took place 2 weeks before the renewal of dams. The shoots slowed the impact of rain drops and thanks to this erosion of ridge sides was reduced which led to better preservation of the reservoir volume in period after their renewal than before it. The greatest outflow in case of variants with tied ridging came in the IV period, when in short intervals there were recorded rainfalls with intensity of 5.1 mm in 15 min and quantity of 8 mm and daily rainfalls of 18 mm.

In case of variants without reservoirs the intensity of erosion was higher before 23.6. (1/3 of the whole season). This fact was probably caused by additional erosion from ridges as a consequence of 3 rainfall events with high intensity on 13.5., 30.5 and 13.6. In the remaining 2/3 of season the ridges were protected more by vegetation cover and erosion took place mainly in the furrows. Entrainment effect of running water on soil particles causing erosion is slowed with tied ridging by formed reservoirs. Daily quantity of rainfall of 32 mm and rainfalls with intensity of 6 mm in 15 min after dam renewal did not have any influence on runoff and the intensity of erosion in variants RF and TRF in comparison to the F and TF variants.

The renewal of reservoirs, carried out up to vegetation cover (23.6.) led to an increase of water retention from rainfalls, which considerably increased in further course of the season (Fig. 6). Tied ridging led to higher utilization of rainwater and lower losses of soil and after renewal of reservoirs these benefits increased further (Table 2 and Table 3). Comparing the trail variant (TF) and the non-trail variant without reservoirs (F) outflow and erosion were higher in TF (58% vs. 42%). Calculated to unit area m^2 it was 52% vs. 48%.

Retained water in case of TRF variant in the period up to the renewal of dams represented 7.7% of water precipitated on its area. After renewal of reservoirs, the retained quantity of water was higher – 15.7%. In total, for the whole season, reservoirs in the trail variant (TRF) retained 14.5% of total rainfall on its area which was 55% of total quantity of retained water in the technology of tied ridging (RF+TRF). Reduction in erosion intensity achieved in the case of TRF was 71% before renewal of reservoirs and 96% afterwards.

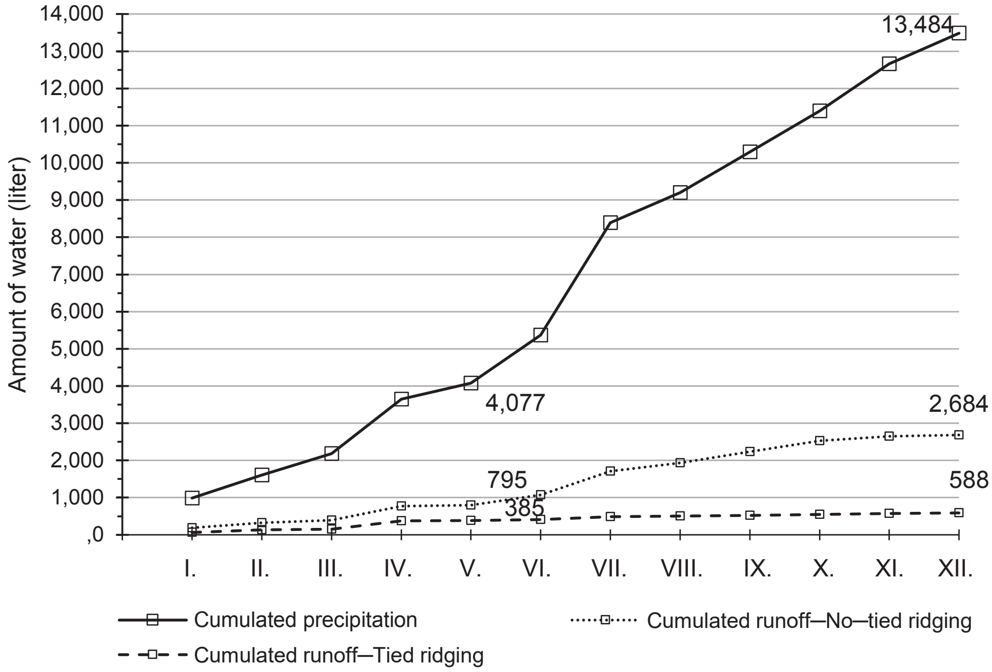

Figure 6. Balance of water on the research areas (54 m^2) in individual periods of sampling.

Technology of tied ridging retained 10% of rainwater before the renewal of reservoirs and 17% afterwards. In total, for the whole monitored period of 135 days following planting, the savings of water by using of this technology compared to regular technology were 15% from fallen rainfalls. This quantity of saved water, which represented 2,096 litres on an area of 54 m^2, would have drained away without the use of the tied ridging technology.

At the end of potato season, the variants of trial with the technology of tied ridging (RF+TRF) 78% lower surface runoff and 88% lower loss of soil (Tables 2 and 3) in comparison with variant without it (F+TF). On the F and TF variants the loss of soil was 107 kg of soil on an area of 54 m^2 across the monitored period.

Table 2. Runoff from individual variants and savings by tied ridging technology

Runoff in liter (l)	From planting until renewal of dams (9.5.–22.6.)	Save (9.5.–22.6.) of ridging technology in %	From renewal of dams until end of season (23.6.–27.9)	Save (23.6.–27.9.) of ridging technology in %	Whole season	Save of ridging technology in %
Tied ridging (RF+TRF)	385		204		588	
No-tied ridging (F+TF)	795		1,889		2.684	
Ridging furrow (RF)	92		60		152	
Furrow (F)	319		784		1,103	
Trail ridging furrow (TRF)	293		143		436	
Trail furrow (TF)	476		1,105		1,581	

Table 3. Erosion rate of individual variants and savings by tied ridging technology

Erosion in kilogram (kg)	From planting until renewal of dams (9.5.–22.6.)	Save (9.5.–22.6.) of ridging technology in %	From renewal of dams until end of season (23.6.–27.9)	Save (23.6.–27.9.) of ridging technology in %	Whole season	Save of ridging technology in %
Tied ridging (RF+TRF)	10.6		1.7		12.3	
No-tied ridging (F+TF)	54.8		52.1		106.9	
Ridging furrow (RF)	1.7		0.6		2.3	
Furrow (F)	23.4		21.1		44.5	
Trail ridging furrow (TRF)	8.9		1.1		10.0	
Trail furrow (TF)	31.4		31.0		62.4	

The significant differences of surface runoff between variants with tied ridging technology (RF, TRF) and without technology (F, TF) were proven by statistical analysis (Table 4). Significants differences could be also proven between variants in furrow (F) and in trail furrow (TF) without tied ridging technology. On the contrary, the differences between furrow (RF) and trail(TRF) in tied ridging technology were comparable and significant differences did not show.

Table 4. Tukey HSD test for surface runoff

Variants	Surface runoff (liter) – Mean	1	2	3
RF	4.219	a		
TRF	12.124	a		
F	30.761		b	
TF	45.161			c

Alfa = 0.05; RF – ridging furrow; TRF – trail ridging furrow; F – furrow, TF – trail furrow.

Tied ridging in interrows of potatoes, as an effective measure for reduction of surface runoff of water and loss of soil from land, is mentioned in case of trials in Canada on the Prince Edward Island by Gordon et al. (2011). By application of a single tied ridger without planter on fields with the length of 25 m with the slope of 3–5°, a reduction of surface runoff by 75% was achieved as well as 89% reduction of soil erosion. The basins had a length of 1 meter with a volume of 5.25 litres. Authors mention the reduction of retention space at the end of season by 1/3 in comparison with original volume at the beginning of season.

Positive effects of tied ridging technology during simulated 14 mm rainfall were observed in the trials of Müller et al. (2009) in Sachsen, Germany. Surface runoff on the 6 m plots on loess came after 400 seconds in the variant with tied ridging, however in the variant without this technology runoff started just after 50 seconds. During the time of runoff retention in reservoirs the water would carry away 270 kg of soil per hectar in the control variant.

Billen & Aurbacher (2007) measured the surface runoff in a trial with simulation of rain with intensity from 50 to 100 L m^{-2} per hour. The surface runoff was 1% from total rainfall in tied ridging technology against 14% to 52% in a variant without technology.

Olivier et al. (2011) carried out studies in the Flemish region in Belgium on 30 m plots with the length of basins 1.6 m. From May to September the efficiency of technology was monitored during various rainfall events. The authors mention a great effect on reduction of technology efficiency owing to an extreme rainfall. Up to the torrential rainfall in August of 40 mm, which was recorded on the 106th day from the beginning of measurement, the water runoff had been lower by 85% and after it only by 10–20%. In total, for the whole monitored season the authors achieved in their trials for 120 days runoff lower by 50% with the use of a single tied ridger in comparison with conventional technology.

Some disadvantages of this technology have been recorded from the experience of farmers. In the case that tied ridging is performed as a separate operation, the costs are rising and the soil is compacted repeatedly by machine passages. Another limiting factor of the system is the formation of bumps, which make the work of machinery on soil difficult (Applied Research Forum, 2007).

CONCLUSIONS

A high efficiency of agricultural anti-erosion technology of tied ridging to reduce surface runoff of water and soil erosion during cultivation of potatoes was confirmed. A substantial reduction in both surface runoff and erosion intensity are also mentioned in other studies worldwide. Extreme rainfalls can significantly reduce the efficiency of tied ridging technology. In our study, there were used greater number of smaller reservoirs of shorter length compared to the other studies and after 1/3 of season their renewal was carried out.

As a result of stronger rainfalls and lack of vegetation cover considerable erosion of soil can occur, which settles in reservoirs formed in soil in case of tied ridging technology. These reservoirs prevent erosion of soil from the field, but at the same time this material reduces the retention capacity of these reservoirs and it results in a reduction of efficiency of this technology. After 1/3 of season considerable filling of reservoirs has been recorded with reduction of initial volume by 30–50%. In order to increase the efficiency, it is suitable to carry out a renewal of reservoirs up to the time of closing of plant cover which will increase again their volume. As a consequence of developed vegetation cover formed by shoots there is not significant erosion and larger accumulation potential is restored for outflowing water which can be retained. Without renewal of reservoirs, the savings of water would range between 10–17% of the total rainfalls. By renewal of dams 1.7 x more water was retained in following 90 days from total rainfalls than in the previous 45 days.

By combination of tied ridging during the planting and renewal of reservoirs 15% of water from total rainfalls (37.5 mm of 250 mm) was additionally utilized in the whole period of 135 days. Otherwise this water would have drained away unused.

Soil protection technologies contribute significantly to sustainable agricultural production, reduction of harmful effects on the environment and reduction of consequences of weather extremes. Tied ridging technology improves considerably the water management on the fields and unification of tied ridging technology into one operation together with planting decreases costs and soil damage caused by agricultural machinery.

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REFERENCES

Applied Research Forum. 2007. Soil strategy case study, 5 pp. https://potatoes.ahdb.org.uk/sites/default/files/publication_upload/Soil%20Factor%20-%20Water%20Erosion.pdf. Accessed 1.1.2017

Billen, N. & Aurbacher, J. 2007. Agriculture floods protection – 10 Profiles for 12 Measures – one measure handbook for various transformations, 20 pp. (in German). https://www.uni-hohenheim.de/i410a/steckbriefe/HochwasserSteckbriefe.pdf Accessed 18.4.2017

Gordon, R.J., VanderZaag, A.C., Dekker, P.A., De Haan, R. & Madani, A. 2011. Impact of modified tillage on runoff and nutrient loads from potato fields in Prince Edward Island. *Agricultural Water Management* **98**, 1782–1788.

Hůla, J., Novák, P., Petrásek, S., Kovaříček, P. & Procházka, P. 2010. Surface water runoff and erosive wash at cultivation of maize and oats. *Agritech Science* **4**(3), pp 5. (in Czech) http://www.agritech.cz/clanky/2010-3-5.pdf Accessed 18.4.2017

Hůla, J., Kovaříček, P., Novák, P. & Vlášková, M. 2016. Surface water runoff and soil loss in maize cultivation. In: Herák, D., Chotěborský, R., Kovář S., KŘEPČÍK, V. *Proceeding of 6th International Conference on Trends in Agricultural Engineering 2016*. Prague, Czech University of Life Science, 201–205.

Kovář, S., Kovaříček, P., Novák, P. & Kroulík, M. 2016. The effect of soil tillage technologies on the surface of the infiltration speed of water into the soil. *Agronomy Research* **14**(2), 434–441.

Javůrek, M., Kovaříček, P., Vach, M. & Hůla, J. 2012. Suitable soil management can increase the topsoil protection against water erosion. *Úroda* **60**(11), 50–53. (in Czech)

Mayer, V., Vacek, J., Stehlík, M. & Vejchar, D. 2016. The controlling erosion technology of soil conservation in potato cultivation. *Úroda* **64**(1), 50–55. (in Czech)

Müller, E., Becherer, U. & Hänsel, M. 2009. Measures for reduction of erosion in the conventional and ecological agriculture included specific soil cultivation. In *Erosionsminderung in der Landwirtschaft* **2**, 78 pp. (in German). https://publikationen.sachsen.de/bdb/artikel/14995/documents/17995 Accessed 18.4.2017

Munodawafa, A. 2012. The effect of rainfall characteristics and tillage on sheet erosion and maize grain yield in semiarid conditions and granitic sandy soils of Zimbabwe. *Applied and Environmental Soil Science* **2012**, pp. 8.

Olivier, C., Goffart, J-P., Baets, D., Fonder, N., Bathélemy, J-P, Lognay, G. & Xanthoulis, D. 2011. Tied ridging in the furrows of potato culture: experiment realized from cooperation with Bayer CropScience (Huldenberg 2011), *Brochure du Centre Pilote Pomme de terre–FIWAP* **9.5**, 7 pp. (in French). http://hdl.handle.net/2268/156693 Accessed 1.1.2017

Vacek, J., Mayer, V., Dovol, J. & Novák, J. 2015. Erosion control measures in the stone windrowing technology for potatoes. *Úroda* **63**(12), research attachement, 335–338. (in Czech). http://www.vupt.cz/content/files/aktualni_poznatky/2015_priloha_Uroda_12.pdf Accessed 18.4.2017