https://doi.org/10.17221/149/2023-PSE

Different technologies of potato (*Solanum tuberosum* L.) cultivation and their effects on water runoff and soil erosion

Jiří Záruba[1,2], *Pavel Formánek*[1]*, *David Kincl*[1,2], *Jan Vopravil*[1,2], *Helena Kusá*[3], *Pavel Růžek*[3], *David Kabelka*[1,4], *Pavel Kasal*[5]

[1]*Research Institute for Soil and Water Conservation, Prague, Czech Republic*
[2]*Department of Land Use and Improvement, Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Prague – Suchdol, Czech Republic*
[3]*Crop Research Institute, Prague, Czech Republic*
[4]*Department of Agroecosystems, Faculty of Agriculture and Technology, University of South Bohemia, České Budějovice, Czech Republic*
[5]*Potato Research Institute Havlíčkův Brod, Havlíčkův Brod, Czech Republic*

**Corresponding author: formanek.pavel@vumop.cz*

Citation: Záruba J., Formánek P., Kincl D., Vopravil J., Kusá H., Růžek P., Kabelka D., Kasal P. (2023): Different technologies of potato (*Solanum tuberosum* L.) cultivation and their effects on water runoff and soil erosion. Plant Soil Environ., 69: 238–246.

Abstract: Surface runoff and soil losses in the case of potato cultivation using de-stoning technology on gentle slopes (Haplic Cambisol) were studied in 2020–2022. Different ridges shapes were compared: control (smooth shaped ridges), pits, pits plus loosening, pits plus loosening plus cover crop (*Triticum aestivum* L.) sowing in trail furrows. Runoff and soil losses were studied approximately 1 and 2 months after planting potatoes. The obtained results showed the highest reduction of surface runoff and soil losses in the treatment with cover crop sowing. In this variant, soil losses were reduced by 65–81% (1 month after planting) and 54–85% (2 months after planting) in case of simulated rainfall on the soil with natural moisture (or these losses were reduced by 51–93% and 50–76% in case of 15-min rainfall). On average, tuber yields reached 29.4 t/ha (pits + loosening) to 30.6 t/ha (pits) in 2020–2022. The different abilities of the tested shapes of ridges and furrows to retain water did not significantly affect the achieved yields of tubers, as rainfall was not a limiting factor in the monitored period. The yield differences among all tested treatments reached units of tons per hectare if the entire dose of nitrogen was applied at planting. Splitting the total nitrogen dose (50% at planting, 50% at loosening) gave significantly ($P < 0.05$) higher yields (34.2 t/ha) than a single application at planting. The treatment pits plus loosening with fertilisation provided a 19–26% higher tuber yield than pits plus loosening with a total N dose applied at planting.

Keywords: crop canopy; erodibility; fertiliser; water retention; wheat

More than 50% of agricultural land is threatened by water erosion (and approximately 10% by wind erosion) in the Czech Republic; also, 5–10% of forest soils are damaged by water erosion etc. For example, healthy forests usually protect soils from erosion; the network of forest roads, including skid trails, was shown to alter hydrological processes and cause soil erosion by water (Zemke 2016). Concerning soil erosion, the cultivation of potatoes is problematic. Potato cultivation may lead to water and wind (and tillage and harvest) erosion (e.g., Chow and Ress 1994, Sharratt and Colins 2018, Nyawade et al. 2019,

Supported by the Ministry of Agriculture of the Czech Republic, the Projects No. MZE-RO0223, QK1910382 and QK21010161.

https://doi.org/10.17221/149/2023-PSE

Lemann et al. 2019, Edwards et al. 2020). For example, Chow and Ress (1994) studied the effect of hilling (*Solanum tuberosum* L.) on surface runoff, infiltration and soil erosion using a rainfall simulator (hilled versus unhilled plots). The authors state that the use of hilling caused higher runoff (mean runoff rate was 20% higher), lower infiltration (30% lower) and approximately four times higher soil losses compared with unhilled plots. Nyawade et al. (2018) studied sediment particle size distribution and soil organic matter losses (including soil organic matter fractions) in the case of potatoes intercropping with different legumes. Concerning potato intercropping, see Ren et al. (2019), Zhang et al. (2020), etc. To reduce soil erosion during potatoes cultivation (slow emergence), Jemison (2019) tested nurse crops, including seeding rates, duration and the use of herbicides before incorporation into the soil. Partitioning of rainfall by crop canopies (interception, throughfall and stem flow) may influence erosional processes (Ma et al. 2013, 2015). Janeau et al. (2015) studied stem flow in the case of different plants, including *Solanum tuberosum* L. (the stage of potatoes growth = maturity). Concerning potatoes, the authors found that stem flow formed 30% of total simulated rain at an intensity of 27 mm/h (and 15% of rain at an intensity of 70 mm/h). Saffigna et al. (1976) used a tracer (Rhodamine WT) to study infiltration in the case of *Solanum tuberosum* L., cv. Russet Burbank; for example, the authors state that stem flow increased water content around the stems. Albedo of potato fields was found to be 9–21%; for example, the values 13–25% (wheat) and 14–36% (barley) were reported in different publications (e.g., Tajchman 1971, Piggin and Schwerdtfeger 1973). Also, Aksic et al. (2014) showed the effect of matric potential (or water consumption for evapotranspiration) on potato yields etc. (Kang et al. 2004).

Concerning potatoes cultivation, increasing potatoes yields per hectare and decreasing the area of potatoes cultivation in the Slovak Republic (the period from 1950 to 2017) are described in Koco et al. (2020). The authors also state different soils on which potatoes are cultivated (Cambisols – 28% of the potato cultivation areas, Chernozems – 20%, Fluvisols – 18%, Dystric Planosols – 11%), including texture, the content of gravel, depth, slopiness. According to Koco et al. (2020), 26% of the areas are in the Slovak Republic's very warm, very dry climatic region (and 14% in a very cold, wet climatic region).

Potatoes are grown almost exclusively in technology with de-stoning in the traditional potato-growing region of the Czech Republic. Furrowing and namely stone and clod separation causes intensive soil aeration and mineralisation of organic matter; therefore, this technology highly demands returning organic matter to the soil. Cattle manure is usually ploughed in autumn, mineral fertilisers (P, K) are continuously applied in the spring before de-stoning, and nitrogen fertilisers when planting directly into ridges. Placement of fertiliser N in the ridges has a positive effect of N recovery in comparison with broadcast fertilisation, especially when the total amount of nitrogen is applied at planting (Maidl et al. 2002). The seed tuber is the primary nutrient and energy source for developing shoots during the first 30 days after planting, and soil N uptake is minimal. Between 30 and 55 days, roots begin to provide nutrients. Only about 20% of the crop N uptake occurs by the end of this period, and therefore high rates of fertiliser N applied prior to this stage may increase the risk of nitrate leaching and nitrous oxide emissions (Zebarth and Rosen 2007). Potatoes require large amounts of nitrogen over a relatively short period of rapid growth (lasting 30 to 50 days with a view to cultivar). As published by Kelling et al. (2015), the efficiency of applied nitrogen can be increased by splitting the in-season N applications and different ridge shapes. Modification of the ridge shape affects water infiltration into the ridge and soil moisture. Improving fertiliser nitrogen use efficiency is an opportunity, especially on sandy soil (Jordan et al. 2013).

In this study, we attempted to determine runoff and soil losses in the case of potato cultivation on gentle slopes with the use of different technologies, which are described below. We hypothesised that using technologies with treatment in both trail and non-trail furrows would lead to the highest reduction of runoff and soil losses (e.g., Vejchar et al. 2017). We also hypothesised a reduction of runoff (rather than soil losses), especially when the technologies with the restoration of pits in the non-trail furrow (at the beginning of emergence) will be used. The second question was whether the different shapes of ridges and more water retention affect the tuber yields achieved. There was a risk that the plants under the pits would be less profitable (than below the dams) due to the shallower planting of the tubers. The impact of cover crops in the trail furrow on the yield in the adjacent ridges was also studied. And finally, the effect of the different timing of nitrogen application on potato yield was observed.

https://doi.org/10.17221/149/2023-PSE

MATERIAL AND METHODS

The experiments were performed near Věž in Havlíčkův Brod district (the Bohemian-Moravian Highlands) in the Czech Republic (the years 2020–2022) – gentle slopes (Haplic Cambisol – IUSS Working Group WRB (2015), an average altitude = 605 m a.s.l.). This area is characterised by a mean annual air temperature of 5–6 °C and by a mean annual precipitation of 700–800 mm, and a sum of temperatures above 10 °C between 2 000 and 2 200 (mildly cold, wet climatic region of the Czech Republic) – from data obtained in the period 1950–2021.

The field experiments were established using destoning technology on sloping areas (4.51°, 3.94° and 4.86° in 2020, 2021 and 2022, respectively) with the orientation of the ridges following the fall line in all years. Mineral nitrogen, possibly phosphorus and potassium fertilisers were applied before grooving in April in the following way: NPK 15-15-15 300 kg/ha and ammonium sulphate 300 kg/ha (2020), UAN (urea and ammonium nitrate) 150 L/ha (2021), NP 20-20 200 kg/ha + ammonium sulphate 250 kg/ha (2022). Fertiliser doses were determined by the N_{min}, P and K content in the soil. The total nitrogen doses reached 105, 60 and 90 kg N/ha in 2020, 2021 and 2022, respectively. Planting (cv. Antonia) was realised using innovated planter Grimme GB 230 on May 6, 2020, May 12, 2021, and May 10, 2022. Four treatments were established (the size of individual plots = 900 m^2): (1) control (smooth shaped ridges); (2) pits (large pits and transversal dams on the top of ridge, transversal dams in non-trail furrow formed at planting); (3) pits plus loosening (the same as 2 plus loosening of ridges top and restoration of pits in non-trail furrow at the beginning of plants emergence with the possibility of in-season fertilisation); (4) pits plus loosening plus sowing (the same as 3 plus sowing of cover crop, *Triticum aestivum* L., and damming in the trail furrow). Fertiliser $UREA_{stabil}$ (80 kg N/ha) was applied on both tubers' sides in all planting treatments. Treatment 3 was established in two treatments: (3a) 80 kg N/ha at planting and (3b) 40 kg N/ha at planting plus 40 kg N/ha at loosening. Liquid fertiliser UAN was applied from the non-trail furrow to the ridge in the root zone of plants. Loosening of ridges top with the restoration of pits in the non-trail furrow (3a), possibly with in-season fertilisation (3b), and cover crop sowing and damming in the trail furrow (4) was carried out on May 27, 2020, June 7, 2021, and June 6, 2022. The pre-emergence herbicide (Planteen 41.5 WG) was always applied 1–2 days after planting. Applications of other herbicides (Arcade 880 EC, Agil) and fungicides against late blight were carried out regarding current needs and the prognosis of late blight occurrence in individual experimental years. Nine applications of fungicides in the sequence Ridomil Gold MZ Pepite (active substance: Mancozeb, Metalaxyl-M) 2×, Revus Top (a. s. Difenoconazole, Mandipropamid) 2×, Infinito (a. s. (Fluopicolide, Propamocarb hydrochloride) 2×, Vendetta (a. s. Azoxystrobin, Fluazinam) 1×, Ranman Top (a.s. Cyazofamid) 2× were carried out under conditions of strong fungal infection pressure in 2020 and 2021. Only seven applications (Revus Top 3×, Infinito 2×, Vendetta 2×) were needed in 2022. The insecticides Biscaya (Thiacloprid) (2020 only), Coragen (Chlorantraniliprole) and Spintor (Spinosad) were used against the potato beetle. Potato harvest (four plots per treatment) with a small plot harvester occurred on September 17, 2020, September 27, 2021, and October 10, 2022. The influence of different planting depths (under a pit or a dam) on tuber yield was determined by manually harvesting individual plants. Yield results were statistically evaluated by one-way analysis of variance and Tukey's *HSD* (honestly significant difference) test at the significance level ($P < 0.05$). Statistically, significantly different values are marked with different letters (a, b).

In 2020–2022, the rainfall simulations were realised approximately 1 month after planting (the first term) and 2 months after planting (the second term). The used field rainfall simulator (a size of rainfall simulation area = 21 m^2, the intensity of rainfall 1.2 mm/min) plus measurement principles are described in different publications (e.g., Kabelka et al. 2019, 2021, Kincl et al. 2021). All rainfall simulations were done twice consecutively (the first measurement = 30 min of simulated rainfall on the soil with natural moisture; after 15 min of technological break, the second 15-min rainfall simulation on the same and saturated soil). Statistical testing was realised with the use of a *t*-test.

RESULTS AND DISCUSSION

Rain simulations. In 2020 (approximately 1 month after planting), the soil losses were the lowest in the treatment with pits plus loosening plus sowing, pits or pits plus loosening (Figure 1). These losses were 65, 31 or 22% lower than the control treatment (the first rainfall simulation = the soil with natural

https://doi.org/10.17221/149/2023-PSE

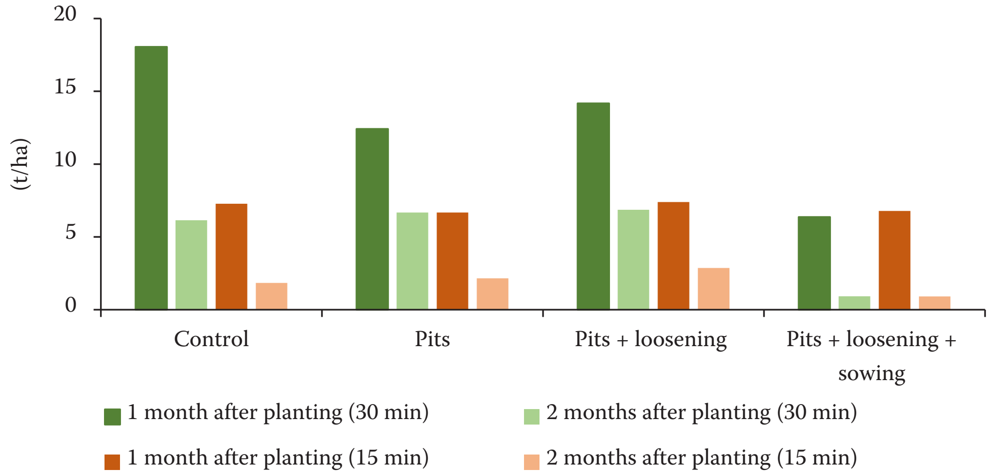

Figure 1. The values of soil loss in individual treatments of potato (*Solanum tuberosum* L.) cultivation in 2020

moisture, 30 min of simulated rainfall). Runoff values decreased by 31% (pits plus loosening plus sowing), 22% (pits plus loosening) or 4% (pits) compared with the control. Two months after planting (= the second term), the loss of soil was lower in the case of the treatment with pits plus loosening plus sowing (by 85%) compared with the control; in the other treatments (pits, pits plus loosening), soil losses were higher than those in the control treatment – the first rainfall simulation (30 min). The values of runoff decreased by 29% (pits plus loosening plus sowing), 18% (pits plus loosening), and 13% (pits). In the case of the second simulation (15 min), decreased losses of soil (by 50%) were in the treatment with pits plus loosening plus sowing; in the other treatments, soil losses were higher compared with the control (Figure 1). The runoff values decreased by 2% in the treatment with pits plus loosening plus sowing. In the treatment with pits plus loosening, the runoff values were the same as in the case of the control treatment; higher runoff values were found in the treatment with pits (15-min rainfall simulation).

In the year 2021 (1 month after planting), the soil loss was 19% (pits + loosening + sowing), 57% (pits) or 97% (pits + loosening) of the control (30 min of simulated rainfall) – Figure 2. The runoff decreased in all treatments by 18–35% (the lowest runoff = pits plus loosening). In the case of the second rainfall simulation (15 min), the soil loss was 49% (pits + loosening + sowing), 65% (pits) or 100% (pits + loosening) of the control (Figure 3). The runoff values also decreased in all treatments by 36–42% (the lowest

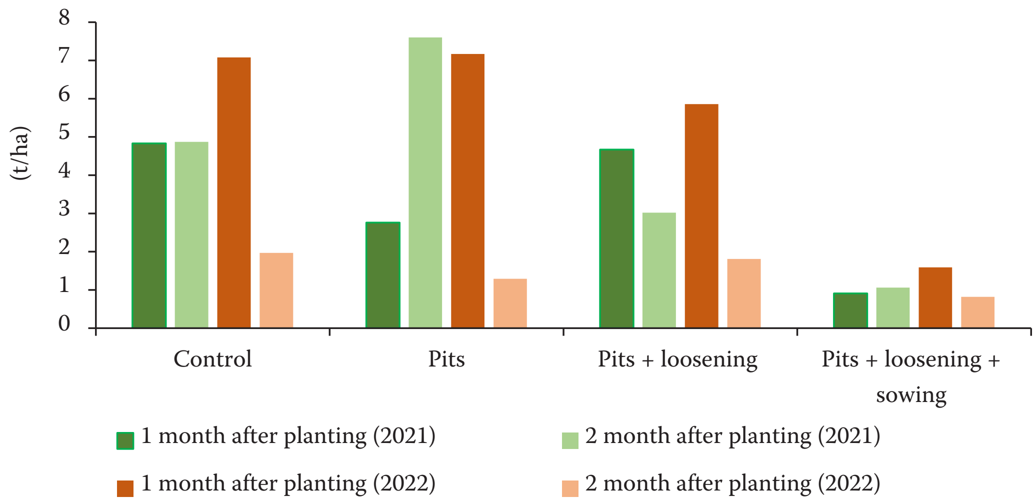

Figure 2. The values of soil loss in individual treatments of potato (*Solanum tuberosum* L.) cultivation in 2021 and 2022 (the first simulation = 30 min)

https://doi.org/10.17221/149/2023-PSE

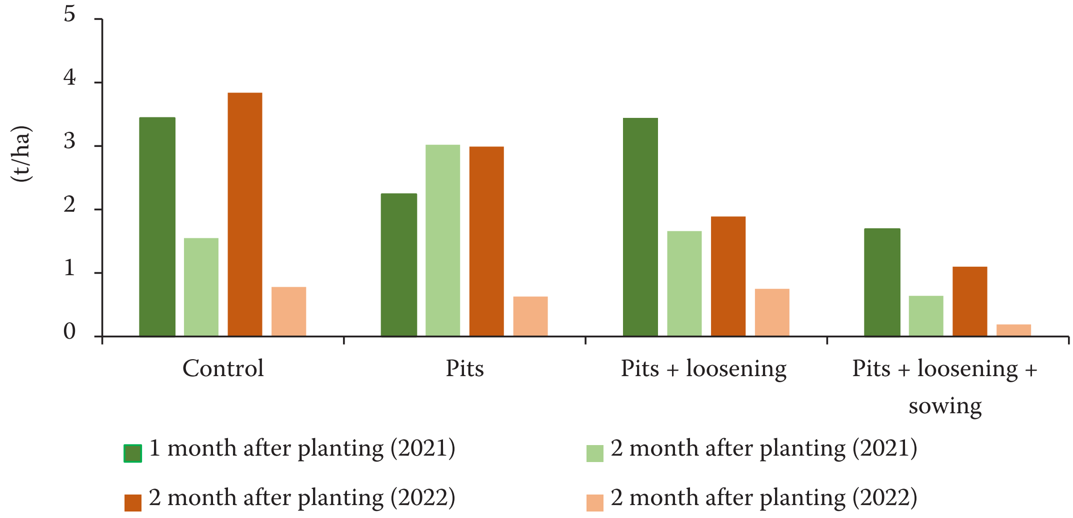

Figure 3. The values of soil loss in individual treatments of potato (*Solanum tuberosum* L.) cultivation in 2021 and 2022 (the second simulation = 15 min)

runoff = pits plus loosening). Two months after planting, soil losses decreased only in the case of pits plus loosening plus sowing (by 78%) or pits plus loosening (by 38%) – 30-min simulation; in the case of 15-min simulation, soil losses were 41% (pits plus loosening plus sowing), 107% (pits plus loosening) and 195% (pits) of the control treatment. Runoff decreased in all treatments (both 30-min and 15-min simulation) by 18–36% (the most efficient treatments = pits + loosening + sowing, pits + loosening).

In 2022 (1 month after planting), the value of soil loss was the lowest in the treatment pits + loosening + sowing (22% of the control); soil losses were similar in the control and treatment with pits (30-min simulation) – Figure 2. Soil losses decreased in all treatments and were the lowest in the case of pits + loosening + sowing (29% of the control) and pits + loosening (49%) (15-min simulation). The runoff values decreased by 22–27% (both 30-min and 15-min simulations). Two months after planting, the highest reduction of soil losses was found in the treatments pits + loosening + sowing (by 58%) and pits (by 35%) – 30-min simulation. Concerning the second rainfall simulation, the reduction was found in all treatments and was the highest in the case of pits + loosening + sowing (76%). The runoff values decreased by 10–24% (30 min of simulated rainfall), and the treatment pits were the most efficient. Concerning 15 min of simulated rainfall, the highest reduction was also found in the case of pits. Concerning the losses of soil (in the period 2020–2022), their significant ($P < 0.05$) reduction was found only in the case of the treatments with cover crop sowing (30-min and 15-min simulation); the values of runoff were significantly ($P < 0.05$) reduced in all treatments (30-min and 15-min simulation) – Table 1.

From all variants tested in 2020–2022, the highest reduction of surface runoff and soil losses was found in the variants with treatment in non-trail and trail furrows. In this variant, soil losses were reduced by 65–81% (1 month after planting) and 54–85% (2 months after planting) in case of simulated rainfall on the soil with natural moisture (or these losses of soil were reduced by 51–93% and 50–76% in case of 15-min rainfall). In the study by Vejchar et al. (2017, 2019), trail furrows formed larger areas in potato cultivation compared with non-trail furrows; higher runoff and soil erosion were in trail compared with

Table 1. *P*-values from statistical testing with the use of a *t*-test

	Soil losses		Runoff	
	30 min	15 min	30 min	15 min
Control versus pits	0.2503	0.3416	0.0008	0.0146
Control versus pits + loosening	0.0822	0.3882	0.0003	0.0282
Control versus pits + loosening + cover crop sowing	0.0076	0.0085	0.0017	0.0314

https://doi.org/10.17221/149/2023-PSE

non-trail furrows (the variants with and without tight ridging in trail plus non-trail furrows). Vejchar et al. (2017) compared variants with and without tight ridging (de-stoned soil, a 5% slope); renewal of dams in the tight ridged furrows (10 cm width, basins between them 40 × 25 cm) was performed 14 days after potatoes emergence. As stated by the authors, surface runoff (and soil erosion) were 78% (and 88%) lower in variants with tight ridging; surface runoff or soil erosion from trail furrows formed 58% of total runoff or soil erosion from the variants without tight ridging.

In this study, the treatments with the sowing of wheat (and damming) in trail furrows were the most effective; according to different authors, the use of wheat seems to be more effective in reducing soil losses rather than runoff (Lin et al. 2019, Kincl et al. 2022, etc.). Nyawade et al. (2019) realised a study (Kenya, Nitisols according to FAO) to find the effects of potatoes intercropping with different grain legumes on soil surface roughness, soil losses (and nutrient losses), runoff etc. For example, the authors state that the highest soil losses (and runoff) were found in the case of bare soil; the losses of soil (and runoff) were also higher in the case of pure potato stands (all stages of potato growth – emergence, vegetative, tuber initiation, postharvest) compared with the treatments with legumes. The authors also described higher soil organic carbon (and phosphorus, potassium etc.) export rate in the case of pure potato stands compared with the treatments with intercropping. For example, the use of intercropping improved the dissipative effect of the canopy on the kinetic energy of raindrops. The authors describe a decrease of surface roughness at potato emergence etc.; according to the authors, changes in surface roughness may be given by canopy development, rainfall intensity etc.

Vejchar et al. (2019) studied the effect of tight ridging on surface runoff (de-stoned soil, an 8.8% slope) and potato yields (reservoirs at 50-cm intervals, 2-L volume). The authors state that the use of tight ridging led to a reduction of surface runoff by 43–78% compared with the control. For example, Vejchar et al. (2019) mentioned that the filling of reservoirs (sediment) was more pronounced before the development of foliage; the authors recommended that the reservoirs can be restored before foliage development. It was stated by Vejchar et al. (2019) that the efficiency of tight ridging in trail furrows was lower compared with that in non-trail furrows; according to the authors, it was because of the same dimensions of reservoirs (trail and non-trail furrows) and larger areas of trail furrows in potato cultivation. Also, Vacek and Vejchar (2017) reported that soil losses in furrows or trail furrows were lower in the case of pits (with or without their renewal) compared with the control. Concerning this study, it is worth mentioning runoff reduction in the case of pits plus loosening. It is reduced by 22–35% (1 month after planting) and by 11–34% (2 months after planting) in case of 30-min rainfall; in case of 15-min rainfall, the runoff was reduced by 6–42% (1 month after planting) and 0–29% (2 months after planting).

Tuber yields. The potato tuber yields achieved were low (25.3–27.2 t/ha) due to the short vegetation season in 2020. The slow and long emergence of the crop during the cold and wet month of May and the early termination of the vegetation season due to the strong attack of the late blight were the causes. The ridges shape, cover crop in furrow, or nitrogen doses splitting did not significantly affect tuber yields. The smooth control ridge yielded 26.5 t/ha. The other treatments were at the level of 95–103% of the control (Figure 4A). The results achieved in 2021 and 2022 were similar (Figures 4B and 4C). No significant differences in tuber yields were found between the treatments with applying the total nitrogen dose at planting. They reached 32.2–32.8 t/ha and 30.2–32.1 t/ha for these treatments and were at the level of 100–102% and 98–104% of control in 2021 and 2022, respectively. The highest yields of tubers (39.0 and 38.1 t/ha in 2021 and 2022, respectively) were found in the treatment with pitting and fertilisation during loosening at the beginning of stand emergence (treatment 3b). They achieved 121% and 124% of control, respectively, and were statistically significantly higher from all treatments with nitrogen application at planting only.

The high amount of precipitation (86–98 mm) between planting and fertilising at the beginning of plant emergence (3–4 weeks) was probably the cause. Nitrogen applied at planting may have been washed away from the plant roots before the plants took it up. This is also confirmed by the results of field experiments with fertilisers labelled with the ^{15}N isotope carried out at the same time at a site 10 km away, where statistically significantly higher tuber yields and nitrogen utilisation from fertilisers were found in the treatment with pitting and fertilisation at loosening compared to a total N dose fertiliser application at planting (Kusá et al. 2021). The positive effect of divided doses of nitrogen on the yield of

https://doi.org/10.17221/149/2023-PSE

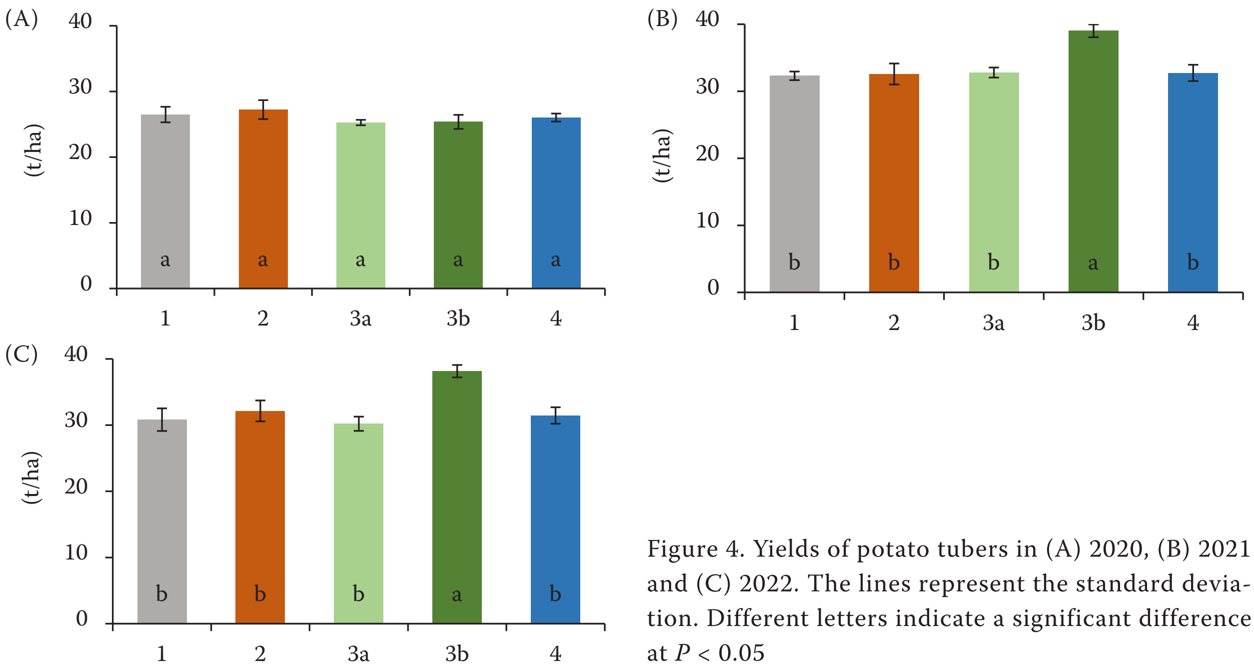

Figure 4. Yields of potato tubers in (A) 2020, (B) 2021 and (C) 2022. The lines represent the standard deviation. Different letters indicate a significant difference at $P < 0.05$

potato tubers, N utilisation and limitation of nitrate leaching, especially on sandy soils, was also confirmed by other authors (e.g. Shrestha et al. 2010, Kelling et al. 2015). The seed tuber is the primary source of nutrients and energy during sprout development, lasting approximately 30 days (Zebarth and Rosen 2007). This period is risky regarding nitrate leaching. Furthermore, high N supply at the first growth stages suppresses or delays tuber bulking (Biemond and Vos 1992).

The tested modifications of ridges and furrows reduced surface runoff and increased soil water content in the ridges compared to the control. The highest volumetric soil moisture in the ridges found in the tuber initiation phase was always the highest in the "pits" treatment and the lowest in control. The differences in individual years ranged from a few tenths of a percent to 2.2% VWC (volumetric water content). It was assumed that higher wetting of modified ridges and better water availability for plants would contribute to higher yields of potato tubers. The experiments described in this study did not unequivocally disprove the assumption, as rainfall was not a yield-limiting factor in 2020–2022.

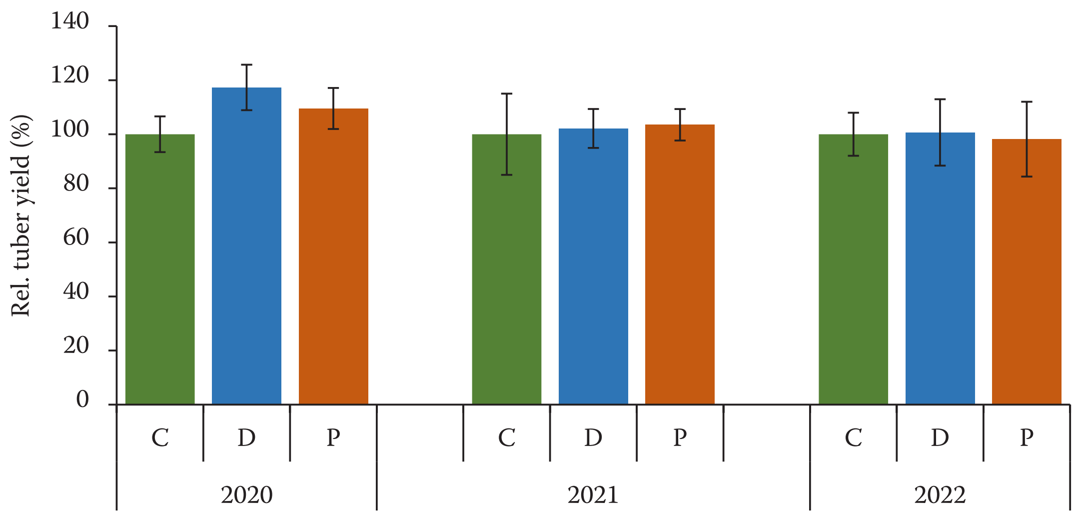

Figure 5. The relative yield of tubers on the control treatment (C) and treatment 2 under dams (D) and pits (P). Control = 100%. The lines represent the standard deviation

https://doi.org/10.17221/149/2023-PSE

Jordan et al. (2013) confirmed that more blocky ridges could significantly improve potato yield, quality, and N-use efficiency than pointed ridges on sandy soil. No modification of the top of the blocky ridges gave conclusively the best results – in two years out of three, ridges with a standard plateau were more profitable, and in the third with a shaped plateau with the groove on the top.

All ridge and furrow treatments tested were beneficial in reducing water erosion compared to the control. There was a risk of lower yields due to some treatments. The tubers planted under the pits were placed more shallowly than in the ridge with a smooth surface, and therefore the deployment of a smaller number of tubers and a lower total yield on the treatments with pits could have occurred. Tuber number per plant under the pit was always lower than under the dam (by 1–1.4 tuber/plant), but only in one year out of three, it was lower than in control smooth ridge as was found by manual harvesting of individual plants. Figure 5 documents the yields of tubers under the dam and pit at the level of 101–117% and 98–110% of the control. Shallower planting of tubers under the pits did not negatively affect the yield.

The cover crop in the trail furrow competed with potatoes for water and nutrients. Choosing a crop that does not reduce the yield of the main crop is important. Winter wheat in this study was chosen appropriately, as can be seen in Figure 4: potato tuber yields on treatment 3a, "pits + loosening + sowing," were the same or slightly higher than on treatment 4, "pit + loosening". Nyiraneza et al. (2020) also achieved favourable results with cereals. Cover crops spring barley or winter rye improved marketable tuber yields by 9–24%. On the contrary, Gitari et al. (2018) obtained significantly lower tuber yield in intercropping systems with garden peas or climbing beans. These legumes also reduced potato N uptake.

REFERENCES

Aksic M., Gudzic S., Deletic N., Gudzic N., Stojkovic S., Knezevic J. (2014): Tuber yield and evapotranspiration of potato depending on soil matric potential. Bulgarian Journal of Agricultural Science, 20: 122–126.

Biemont H., Vos J. (1992): Effects of nitrogen on the development and growth of the potato plants. 2. The partitioning of dry matter, nitrogen and nitrate. Annals of Botany, 70: 37–45.

Chow T.L., Rees H.W. (1994): Effects of potato hilling on water runoff and soil erosion under simulated rainfall. Canadian Journal of Soil Science, 74: 453–460.

Edwards L.M., Volk A., Burney J.R. (2020): Mulching potatoes: aspects of mulch management systems and soil erosion. American Journal of Potato Research, 77: 225–232.

Gitari H.I., Karanja N.N., Gachene Ch.K.K., Kamau S., Sharma K., Schulte-Geldermann E. (2018): Nitrogen and phosphorous uptake by potato (*Solanum tuberosum* L.) and their use efficiency under potato-legume intercropping systems. Field Crops Research, 222: 78–84.

IUSS Working Group WRB (2015): World Reference Base for Soil Resources 2014. International Soil Classification System for Naming Soils and Creating Legends for Soil Maps. Rome, Food and Agriculture Organisation of the United Nations. (update 2015)

Janeau J.L., Grellier S., Podwojewski P. (2015): Influence of rainfall interception by endemic plants versus short cycle crops on water infiltration in high altitude ecosystems of Ecuador. Hydrology Research, 46: 1008–1018.

Jemison J.M. (2019): Use of nurse crops in potato production to protect soils from erosion. American Journal of Potato Research, 96: 13–20.

Jordan M.O., Kelling K.A., Lowery B., Arriaga F.J., Speth P.E. (2013): Hill shape influences on potato yield, quality, and nitrogen use efficiency. Americal Journal of Potato Research, 90: 217–222.

Kabelka D., Kincl D., Janeček M., Vopravil J., Vráblík P. (2019): Reduction in soil organic matter loss caused by water erosion in inter-rows of hop gardens. Soil and Water Research, 14: 172–182.

Kabelka D., Kincl D., Vopravil J., Vráblík P. (2021): Impact of cover crops in inter-rows of hop gardens on reducing soil loss due to water erosion. Plant, Soil and Environment, 67: 230–235.

Kang Y., Wang F.X., Liu H.J., Yuan B.Z. (2004): Potato evapotranspiration and yield under different drip irrigation regimes. Irrigation Science, 23: 133–143.

Kelling K.A., Arriaga F.J., Lowery B., Jordan M.O., Speth P.E. (2015): Use of hill shape with various nitrogen timing splits to improve fertilizer use efficiency. Americal Journal of Potato Research, 92: 71–78.

Kincl D., Formánek P., Vopravil J., Nerušil P., Menšík L., Janků J. (2022): Soil-conservation effect of intercrops in silage maize. Soil and Water Research, 17: 180–190.

Kincl D., Kabelka D., Vopravil J., Heřmanovská D. (2021): Estimating the curve number for conventional and soil conservation technologies using a rainfall simulator. Soil and Water Research, 16: 95–102.

Koco Š., Vilček J., Torma S., Michaeli E., Solár V. (2020): Optimising potato (*Solanum tuberosum* L.) cultivation by selection of proper soils. Agriculture (Switzerland), 10: 155.

Kusá H., Růžek P., Kasal P., Watzlová E. (2021): Effect of different methods of potatoes fertilization by nitrogen on tuber yield and nitrogen use by plants. Úroda, 12 (scientific appendix): 471–478. (In Czech)

Lemann T., Sprafke T., Bachmann F., Prasuhn V., Schwilch G. (2019): The effect of the Dyker on infiltration, soil erosion, and

https://doi.org/10.17221/149/2023-PSE

waterlogging on conventionally farmed potato fields in the Swiss Plateau. Catena, 174: 130–141.

Lin Q.T., Xu Q., Wu F.Q., Li T.T. (2019): Effects of wheat in regulating runoff and sediment on different slope gradients and under different rainfall intensities. Catena, 183: 104196.

Ma B., Gale W.J., Ma F., Wu F.Q., Li Z.B., Wang J. (2013): Transformation of rainfall by a soybean canopy. Transactions of the ASABE, 56: 1285–1293.

Ma B., Liu Y., Liu X., Ma F., Wu F., Li Z. (2015): Soil splash detachment and its spatial distribution under corn and soybean cover. Catena, 127: 142–151.

Maidl F.X., Brunner H., Sticksel E. (2002): Potato uptake and recovery of nitrogen ^{15}N-enriched ammonium nitrate. Geoderma, 105: 167–177.

Nyawade S., Karanja N., Gachene C., Parker M., Schulte-Geldermann E. (2018): Susceptibility of soil organic matter fractions to soil erosion under potato-legume intercropping systems in central Kenya. Journal of Soil and Water Conservation, 73: 567–576.

Nyawade S.O., Gachene C.K.K., Karanja N.N., Gitari H.I., Schulte-Geldermann E., Parker M.L. (2019): Controlling soil erosion in smallholder potato farming systems using legume intercrops. Geoderma Regional, 17: e00225.

Nyiraneza J., Hann S., Owen J., Zebarth B.J., Stles K., Fillmore S. (2020): Under-seeding potato with nurse crops in eastern Canada: challenges and opportunities. Canadian Journal of Plant Science, 100: 697–706.

Piggin I., Schwerdtfeger P. (1973): Variations in the albedo of wheat and barley crops. Archiv für Meteorologie, Geophysik und Bioklimatologie, Serie B, 21: 365–391.

Ren J., Zhang L., Duan Y., Zhang J., Evers J.B., Zhang Y., Su Z., van der Werf W. (2019): Intercropping potato (*Solanum tuberosum* L.) with hairy vetch (*Vicia villosa*) increases water use efficiency in dry conditions. Field Crops Research, 240: 168–176.

Saffigna P.G., Tanner C.B., Keeney D.R. (1976): Non-uniform infiltration under potato canopies caused by interception, stemflow, and hilling. Agronomy Journal, 68: 337–342.

Sharratt B.S., Collins H.P. (2018): Wind erosion potential influenced by tillage in an irrigated potato-sweet corn rotation in the Columbia Basin. Agronomy Journal, 110: 842–849.

Shrestha R.K., Cooperband L.R., MacGuidwin A.E. (2010): Strategies to reduce nitrate leaching into groundwater in potato grown in sandy soils: case study from north central USA. American Journal of Potato Research, 87: 229–244.

Tajchman S.J. (1971): Evapotranspiration and energy balances of forest and field. Water Resources Research, 7: 511–523.

Vacek J., Vejchar D. (2017): Soil conservation tillage of dammer diking for potato growing in destoned hills. Úroda, 12: 501–504. (In Czech)

Vejchar D., Stehlik M., Mayer V. (2017): Influence of tied ridging technology on the rate of surface runoff and erosion in potato cultivation. Agronomy Research, 15: 2207–2216.

Vejchar D., Vacek J., Hájek D., Bradna J., Kasal P., Svobodová A. (2019): Reduction of surface runoff on sloped agricultural land in potato cultivation in de-stoned soil. Plant, Soil and Environment, 65: 118–124.

Zebarth B.J., Rosen C.J. (2007): Research perspective on nitrogen BMP development for potato. American Journal of Potato Research, 84: 3–18.

Zemke J. (2016): Runoff and soil erosion assessment on forest roads using a small scale rainfall simulator. Hydrology, 3: 25.

Zhang X., Wu K., Fullen M.A., Wu B. (2020): Synergistic effects of vegetation layers of maize and potato intercropping on soil erosion on sloping land in Yunnan Province, China. Journal of Mountain Science, 17: 423–434.

Received: April 6, 2023
Accepted: May 15, 2023
Published online: May 30, 2023