Research paper

The Influence of Different Cultivation Technologies on the Changes in Quantitative and Qualitative Parameters of Buckwheat

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ABSTRACT

Changes of the quantitative and qualitative parameters of buckwheat were observed on gleyic Fluvisols (locality Milhostov, Slovak Republic) at different tillage between 2013 and 2015. The experiment was conducted using two soil tillage treatments: conventional tillage and reduced tillage, and three conditioner application treatments: soil conditioner PRP SOL, a combination of soil conditioner PRP SOL and plant auxiliary substance PRP SOL+EBV, and control. In buckwheat crops, basic physical properties were also monitored. The statistically significantly higher yields of buckwheat were achieved with reduced tillage. Significant differences were found in buckwheat yield between years. The lowest yields of buckwheat were recorded in the dry and extremely hot year of 2015. In the variant with conventional tillage, better values of basic soil physical properties were recorded compared with the reduced tillage. Significantly higher yields of buckwheat were found with applications of conditioners than in the control. The application of plant auxiliary substance PRP SOL+EBV on the variant with PRP SOL did not substantially increase the yields of buckwheat. The content of nitrogen substances in the grain of buckwheat was dependent on the fertilization options. Higher content of nitrogen substances in the grain of buckwheat was found in the control than with the application of conditioners. A negative correlation was found between the yield and nitrogen substances in the grain of buckwheat (r = -0.74).

INTRODUCTION

Climate change poses a serious challenge to soil in ensuring optimal food production. Intensive agricultural practices and the use of monocultures have led to the loss of biodiversity. Changes in agricultural routines are needed to address biodiversity. There is a need to grow crops that are more resilient to climate change. Such crops include buckwheat, which can be grown in different climatic and soil conditions

Buckwheat (*Fagopyrum esculentum* Moench) is a cereal of growing agricultural and nutritional importance. It is valued for its short vegetation period, adaptability to marginal soils, and high content of protein and minerals, which makes it a valuable raw material for food production.

Quantitative and qualitative parameters of buckwheat are strongly influenced by cultivation practices and climatic conditions (Popovic et al., 2014). Buckwheat grain yields depend on the agro-ecological conditions of its cultivation and sowing times (Ikanović et al. 2013; Mariotti et al., 2016; Mikami et al., 2018; Nikolic et al., 2019; Jukić et al., 2021; Hassona et al., 2024).

The content of nitrogenous substances in buckwheat grain varies differs considerably, not only depending on soil and climatic conditions, but also on the variety and sowing time (Guo et al., 2007; Jukić et al., 2021).

At extremely high temperatures and consequently dried soil, buckwheat could be exposed to water stress because of the thin root system (Zamaratskaia et al., 2024). It should be noted that buckwheat is highly susceptible to dryness, particularly in early growth stages, during rooting, flowering, and the yielding period. However, moisture excess during the later stages of growth also has strong detrimental effects on buckwheat development (Nikolic et al., 2019).

Buckwheat can be cultivated under a reduced tillage system (Chrungoo and Chettry, 2021). Reduced tillage can boost buckwheat crop germination and establishment by creating a seedbed that facilitates optimal seed-to-soil contact. Nevertheless, buckwheat can be drilled without tillage, which is a viable choice especially for mid-summer planting. This strategy can reduce soil erosion and help preserve soil moisture (Vieites-Álvarez et al., 2024).

The nutrient requirements of buckwheat are low, and intensive fertilization is not required because buckwheat can easily absorb macro- and microelements from the soil. Some studies have highlighted the importance of nitrogen fertilization and water management. For instance, Ciftci et al. (2025) demonstrated that the combined application of irrigation and nitrogen fertilization significantly increased grain yield and protein content.

Despite these findings, relatively little is known about how cultivation technologies interact with soil physical properties (e.g., bulk density, total porosity). Soil conditions can influence quantitative and qualitative parameters of buckwheat. To address this gap, the present study investigates the impact of different tillage practices and conditioner applications on buckwheat yield, grain quality, and soil physical parameters. The aim was to identify cultivation practices that maximize yield and quality while maintaining soil fertility.

MATERIAL AND METHODS

Experimental site and design

The field experiment with different tillage technologies and conditioner applications for buckwheat grown was conducted at the locality Milhostov (National Agriculture and Food Centre – Research Institute of Plant Production – Institute of Agroecology in Michalovce, Slovak Republic) during the 2013-2015 growing seasons. The site is located at (48°40'02.3"N. 21°43'51.2"E), situated in the central part of the East-Slovak Lowland at an altitude of 101 m. The monitored location is included in the climatic region T 03 (Linkeš et al. 1996), which is characterized as warm, very dry, and lowland. The long-term normal (1981 – 2010) for the annual air temperature in Milhostov is 9.4 °C (16.6 °C during the growing season), and the long-term normal for precipitation is 567 mm (374 mm during the growing season) (Mikulová et al. 2020).

Amount of precipitation [mm] and air temperature [°C] in 2013 – 2015 and during vegetation in these years, and their qualitative evaluation are shown in Table 1. The growing season of 2013 and 2014 was warm, and 2015 was very warm. In terms of precipitation, the growing season of 2013 and 2014 was normal, and 2015 was very dry.

The soil was classified as Gleyic Fluvisols, with an initial organic matter content of 2.9 % and a pH in KCl of 6.4. According to the Novak classificatory scale (Zaujec et al. 2009), this soil subtype belongs to heavy soils. The soil particle size distribution before the establishment of experiments with buckwheat is shown in Table 2. The average content of clay particles was 53.2 %.

Table 1. *Amount of precipitation [mm] and air temperature [°C] in 2013 – 2015 and their qualitative evaluation*

Evaluated parameter		DN	2013	2014	2015
Amount of precipitation I.-XII.	[mm]	567	530	613	447
	Percentage to DN [%]	100.0	93.5	108.1	78.8
	Evaluation	-	normal	normal	very dry
Amount of precipitation IV.-IX.	[mm]	374	298	425	227
	Percentage to DN [%]	100.0	79.7	113.6	60.7
	Evaluation	-	normal	normal	very dry
Air temperature I.-XII.	[°C]	9.4	10.3	11.1	11.0
	Deviation from DN [°C]	0.0	+0.9	+1.7	+1.6
	Evaluation	-	warm	extraordinary warm	extraordinary warm
Air temperature IV.-IX.	[°C]	16.6	17.4	17.2	18.0
	Deviation from DN [°C]	0.0	+0.8	+0.6	+1.4
	Evaluation	-	warm	warm	very warm

where: DN – *long-term normal*

Table 2. *Soil particle size distribution before experiment establishment*

Fraction	Values [%]
1st fraction, clay (< 0.001 mm)	30.3
2nd fraction, soft and middle silt (0.001 – 0.01 mm)	22.9
3rd fraction, crude silt (0.01 – 0.05 mm)	27.9
4th fraction, soft sand (0.05 – 0.25 mm)	16.3
5th fraction, middle sand (0.25 – 2 mm)	2.6
Content of particle I. category (< 0.01 mm)	53.2
Soil evaluation	heavy soil, clay-loamy soil

The experiment was arranged in a randomized complete block design with three replications. Treatments consisted of different tillage technologies, including variants in conditioner applications. Plot size with buckwheat was 60 × 45 m, the variant size 15 × 10 m (150 m^2).

Crop management

Sowing common buckwheat (*Fagopyrum esculentum* Moench) variety Hajnalka was carried out in May (3 May 2013, 2 May 2014, 11 May 2015). The experiment was conducted using two soil tillage technologies: conventional tillage and reduced tillage, and three conditioner application treatments: soil conditioner PRP SOL, a combination of soil conditioner PRP SOL and plant auxiliary substance PRP SOL+EBV, and control.

The trial was established with two types of tillage:

CT – conventional tillage – after harvesting of the forecrop, stubble breaking was performed, autumn medium-deep ploughing, spring pre-sowing soil treatment was done using a share cultivator, and sowing.

RT – reduced tillage – after harvesting of the forecrop, stubble breaking was performed, spring pre-sowing soil treatment was done using a share cultivator, and sowing.

The trial was established with three conditioner applications:

PRP – soil conditioner PRP SOL,

PRP+EBV – a combination of soil conditioner PRP SOL and plant auxiliary substance PRP EBV,

C – control.

The soil conditioner PRP SOL was applied for pre-sowing soil preparation at a dose of 200 kg ha^{-1}. The plant auxiliary substance PRP EBV was applied in the 3-leaf phase at a dose of 1.5 l ha^{-1}.

Table 3. *Buckwheat phenology in 2013 – 2015*

Phenology	Year		
	2013	**2014**	**2015**
Sowing	03.05.	02.05.	11.05.
Emergence	17.05.	19.05.	26.05.
Spike formation	06.06.	05.06.	21.06.
Flowering	12.06.	14.06.	29.06.
Technological maturity	20.09.	10.10.	05.10.
Harvesting	24.09.	13.10.	07.10.

The beginning of the basic phenological phases of buckwheat growth in 2013 – 2015 is shown in Table 3.

Standard buckwheat management practices (weed control, pest protection) were applied uniformly across all treatments.

All interventions in establishing and maintaining the experiments were carried out in one day, strictly respecting the principles of experimental equality.

Yield assessment

Buckwheat was harvested after reaching harvest maturity with a small-plot combined harvester. Grain yield was determined by weighing harvested seeds. During harvest, grain samples were taken to determine the harvest moisture content. Buckwheat yields were converted to 13 % moisture content and were expressed in t ha^{-1}.

Grain quality analysis

Quality parameters were determined from grain representative samples collected at harvest. The content of nitrogenous compounds in buckwheat grains was determined using the Kjeldahl method according to ISO 1871 (2009). The concentration of nitrogenous substances in buckwheat grain was converted to dry matter and expressed in g kg^{-1}.

Soil physical properties

Selected physical properties of Gleyic Fluvisol were determined from undisturbed soil samples taken in the spring period. Soil samples were collected from each tillage in cylinders of 100 cm^3 at a depth of 0–0.3 m with three replications. Soil bulk density (kg m^{-3}) and total porosity (%) were determined by methods as published by Hrivňaková, Makovníková et al. (2011).

Statistical analysis

Differences between treatment means were assessed by the least significant difference (LSD) test at $p < 0.05$. All statistical analyses were performed using the Statgraphics software package. Interrelationships between monitored parameters were evaluated using regression analysis.

RESULTS AND DISCUSSION

Buckwheat grain yield

The buckwheat grain yield was significantly influenced by the applied cultivation tillage (Table 4). The statistically significantly highest yield was obtained under reduced tillage (average 1.40 t ha^{-1}), while the lower yield (average 1.29 t ha^{-1}) was recorded in conventional tillage.

In none of the monitored years did the buckwheat yield exceed 2 t ha^{-1} on heavy soils. Similar low yields were obtained in Sweden, where, however, buckwheat yield varied in a wide range depending on the type of buckwheat (Knicky et al., 2024).

Without the application of conditioners, the yield was 1.27 t ha^{-1} with conventional tillage and 1.31 t ha^{-1} with reduced tillage in 2013. The application of soil conditioner, as well as in combination with the plant auxiliary substance EBV, increased the yield by approximately 0.5 t ha^{-1} (Table 5).

In 2014, yields were below 1.50 t ha^{-1}, with a tendency to increase with the application of conditioners. In the year of extreme dry in 2015, buckwheat yields were the

Table 4. *Statistical evaluation of the observed parameters*

Source variability	d.f.	Factor	Yield		Nitrogenous substances	
			[t ha^{-1}]	F-ratio	[g kg^{-1}]	F-ratio
Tillage	1	CT	1.29 a	26.15	117.0 a	1.25
		RT	1.40 b		118.1 a	
Conditioner application	2	PRP	1.46 b	79.39	117.9 ab	2.40
		PRP+EBV	1.42 b		116.1 a	
		C	1.17 a		118.6 b	
Year	2	2013	1.62 c	214.59	97.6 a	409.3
		2014	1.34 b		125.4 b	
		2015	1.09 a		129.6 c	
Residual	63					
Total	71					

where: d.f. *– degrees of freedom,* F*-ratio – calculated F–ratio, letters (*a, b, c*) between factors refer to statistically significant differences (α = 0.05) – LSD test*

Table 5. *Buckwheat yield [t ha^{-1}] in 2013 – 2015 at 13 % moisture*

Tillage	Conditioner application	Year		
		2013	2014	2015
Conventional tillage	PRP	1.74	1.24	1.07
	PRP+EBV	1.76	1.36	1.16
	C	1.27	1.17	0.88
Reduced tillage	PRP	1.75	1.46	1.24
	PRP+EBV	1.86	1.44	1.18
	C	1.31	1.34	1.02

where: PRP *– soil conditioner PRP SOL,* PRP+EBV *– a combination of soil conditioner PRP SOL and plant auxiliary substance PRP EBV,* C *– control.*

lowest, reaching only 0.88 t ha^{-1} in the control variant of conventional tillage (Table 5). Weather conditions significantly influenced the yield quantity during the researched period, which was also found by Popović et al. (2014) and Kolarić et al. (2021).

These findings are in agreement with studies reporting that fertilization combined with suitable tillage systems increases buckwheat yield and improves its qualitative parameters (Zhou et al., 2023; Vieites-Álvarez et al., 2024).

Grain quality parameters

Qualitative parameters were also influenced by the use of conditioners (Table 4). Higher content of nitrogen substances in the grain of buckwheat was found in the control than with the application of conditioners.

In terms of the year, statistically significantly, the lowest concentrations of nitrogenous substances in dry matter were measured in 2013, and the highest in 2015 (Table 4). In 2013, the content of nitrogenous substances in grain was only up to 105.0 g kg^{-1} dry matter. In 2014, higher concentrations of nitrogenous substances were measured, and the difference between the variants was minimal in the interval from 123.1 to 127.5 g kg^{-1} dry matter. In 2015, the concentration of nitrogenous substances ranged in a wider interval (Table 6), from 121.3 to 136.3 g kg^{-1} dry matter. Similarly, Knicky et al. (2024) found in buckwheat grain from 10.8 % to 11.4 % protein content, and Domingos and Bilsborrow (2021) found 12 % protein.

No statistically significant differences were found in the concentration of nitrogenous substances between tillage treatments (Table 4).

Table 6. *Nitrogenous substances [g kg^{-1}] in buckwheat grain in 2013 – 2015*

Tillage	Conditioner application	Year		
		2013	2014	2015
Conventional tillage	PRP	89.3	123.1	131.3
	PRP+EBV	93.6	127.5	130.6
	C	98.0	123.1	136.3
Reduced tillage	PRP	105.0	126.9	131.9
	PRP+EBV	98.9	124.4	121.3
	C	100.6	127.5	126.3

where: PRP – *soil conditioner PRP SOL,* PRP+EBV – *a combination of soil conditioner PRP SOL and plant auxiliary substance PRP EBV,* C – *control.*

The content of nitrogenous substances in buckwheat grain is closely related to the achieved grain yield. With higher grain yields, the content of storage substances decreases, including proteins. Therefore, even among the yield and nitrogen substances in the grain of buckwheat was found a negative correlation (r = -0.74).

Based on the determined grain yields and the determined nitrogenous substances content, at the monitored variants of soil tillage and conditioner applications, the nitrogenous substances yield was calculated and expressed in kg ha^{-1} (Table 7).

In terms of tillage, higher nitrogenous substances yield was found with reduced tillage (163.4 kg ha^{-1}) compared to conventional tillage (147.4 kg ha^{-1}). The applications of conditioners had a positive impact on the nitrogenous substances yield. Average nitrogenous substances yield using a combination of soil conditioner PRP SOL and plant auxiliary substance PRP EBV was 166.0 kg ha^{-1}, at using soil conditioner PRP SOL 163.5 kg ha^{-1}, and only 136.6 kg ha^{-1} at the control (Table 7).

Soil physical properties

Research into the basic physical properties of soil in buckwheat crops was also monitored. Table 8 shows the average physical characteristics of the soil determined during different tillage in the monitored period (2013 – 2015).

The average values of bulk density at conventional tillage were from 1229 kg m^{-3} to 1 455 kg m^{-3}, and at reduced tillage in the range 1301 – 1511 kg m^{-3}. In 2015, bulk density values higher than 1400 kg m^{-3} were found, which is the limit value for clay-loam soil according to Act on the Protection and Use of Agricultural Land No.

Table 7. *Nitrogenous substances yield [kg ha^{-1}] of buckwheat in 2013 – 2015*

Tillage	Conditioner application	Year			
		2013	2014	2015	Average
Conventional tillage	PRP	155.4	152.6	140.5	**149.5**
	PRP+EBV	164.7	173.4	151.5	**163.2**
	C	124.5	144.0	119.9	**129.5**
Reduced tillage	PRP	183.8	185.3	163.6	**177.5**
	PRP+EBV	184.0	179.1	143.1	**168.7**
	C	131.8	170.9	128.8	**143.8**
Average tillage	**PRP**	**169.6**	**169.0**	**152.0**	**163.5**
	PRP+EBV	**174.3**	**176.3**	**147.3**	**166.0**
	C	**128.1**	**157.4**	**124.4**	**136.6**

where: PRP – *soil conditioner PRP SOL,* PRP+EBV – *a combination of soil conditioner PRP SOL and plant auxiliary substance PRP EBV,* C – *control.*

Table 8. *Soil physical parameters under different tillage in 2013 – 2015*

Evaluated parameter	Tillage	Year			
		2013	2014	2015	Average
Bulk density [kg m-3]	CT	1372	1229	1455	1352
	RT	1301	1315	1511	1376
	Average	**1337**	**1272**	**1483**	**1364**
Porosity [%]	CT	46.53	52.09	43.29	47.30
	RT	49.26	48.72	41.08	46.35
	Average	**47.90**	**50.41**	**42.19**	**46.83**

where: CT – *conventional tillage,* RT – *reduced tillage.*

220/2004 Coll. (2004). With a higher bulk density of the soil, soil compaction and adverse changes in the water and air regime of the soil may occur.

The variant with conventional tillage, better values of basic physical properties of the soil were recorded (Table 8), i.e. lower values of soil bulk density (average 1352 kg m^{-3}) and higher values of total soil porosity (average 47.30 %) were found in comparison with the reduced tillage (average 1376 kg m^{-3}, respectively 46.35 %).

Swelling and shrinkage processes are typical for heavy soils with a high content of clay particles and affect soil porosity and its changes. Total porosity is a function of bulk density, therefore, its values are lower at higher bulk density. The optimal total porosity for clay-loam soils should be higher than 47% (Act 220/2004 Coll., 2004). Average porosity values for different tillage in 2015 (43.29 % at conventional tillage, 41.08 % at reduced tillage) and the average value of 46.53 % at conventional tillage in 2013 indicate compaction of the soil profile (Table 8).

The claim that soil physical properties subsequently affect buckwheat yields was confirmed by regression analysis. A significant negative correlation was found between soil bulk density and buckwheat yield (r = -0.68, and a significant positive correlation was found between soil total porosity and yield (r = 0.68).

CONCLUSION

This study demonstrated that different cultivation technologies significantly influenced both the quantitative and qualitative parameters of buckwheat, as well as soil physical properties. The statistically significantly higher yields of buckwheat were achieved with reduced tillage (average 1.40 t ha^{-1}) in comparison to conventional tillage (average 1.29 t ha^{-1}).

Optimized application of conditioners produced a higher grain yield, and also a higher nitrogenous substances yield. Average grain yield and nitrogenous substances yield using a combination of soil conditioner PRP SOL and plant auxiliary substance PRP EBV was 1.42 t ha^{-1}, respectively 166 kg ha^{-1}, at using soil conditioner PRP SOL 1.46 t ha^{-1}, respectively 163.5 kg ha^{-1}, and only 1.17 t ha^{-1} grain yield and 136.6 kg ha^{-1} nitrogenous substances yield at control.

The results suggest that integrated buckwheat management approaches, using different tillage and conditioner applications in soil and climatic conditions, can maximize the agronomic and nutritional potential of buckwheat. Such strategies are particularly relevant for sustainable and ecological farming systems, where the balance between yield, quality, and soil conservation is important.

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IZVLEČEK

Vpliv različnih tehnologij pridelave na spremembe količinskih in kakovostnih parametrov ajde

Pri poskusih na lokaciji Milhostov (Slovaška) so bile pri različnih načinih obdelave tal med letoma 2013 in 2015 ugotovljene spremembe kvantitativnih in kvalitativnih parametrov ajde. Poskus je bil izveden z dvema načinoma obdelave tal: konvencionalna obdelava in zmanjšana obdelava, ter tremi načini nanašanja pripravkov: talni kondicioner PRP SOL, kombinacija talnega kondicioniranja PRP SOL in pomožne snovi za rastline PRP SOL+EBV ter kontrola. Spremljane so bile tudi osnovne fizikalne lastnosti. Značilno višji pridelki ajde so bili doseženi z zmanjšanim obdelovanjem tal. Pomembne razlike so bile ugotovljene v pridelku ajde med posameznimi leti. Najnižje pridelke ajde so ugotovili v suhem in izjemno vročem letu 2015. V različici s konvencionalno obdelavo tal so bile ugotovljene ustreznejše vrednosti osnovnih fizikalnih lastnosti tal v primerjavi z zmanjšano obdelavo. Z uporabo kondicionerjev so bili ugotovljeni bistveno višji pridelki ajde kot pri kontrolni različici. Uporaba pomožne snovi PRP SOL+EBV pri različici s PRP SOL ni bistveno povečala pridelkov. Vsebnost dušikovih snovi v zrnju ajde je bila odvisna od možnosti gnojenja. V kontrolnem vzorcu je bila v zrnju ajde ugotovljena višja vsebnost dušikovih snovi kot pri uporabi izboljševalcev. Med pridelkom in dušikovimi snovmi v zrnju ajde je bila ugotovljena negativna korelacija (r = -0,74).