Scientific Papers. Series A. Agronomy, Vol. LXIV, No. 1, 2021
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

MINERAL FERTILIZATION FOR DURUM WHEAT UNDER NON-IRRIGATED CONDITIONS

Angelina MUHOVA, Stefka STEFANOVA-DOBREVA

Field Crops Institute, 2 Georgi Dimitrov Blvd, 6200 Chirpan, Bulgaria

Corresponding author email: muhova.angelina@gmail.com

Abstract

*The aim of the study was to determine the influence of mineral fertilization in the conditions of soil type Pelic Vertisols in durum wheat, variety Progress, grown under non-irrigated conditions. The experiment was set in 1966 in two-field crop system rotation of durum wheat-cotton. The data include 2014/2019. The following fertilization rates were tested: N_{40}, N_{80}, N_{120}, N_{160}; P_{40}, P_{80}, P_{120}, P_{160}; $N_{80}P_{40}$, $N_{80}P_{80}$, $N_{80}P_{120}$, $N_{80}P_{160}$, $N_{120}P_{80}$, $N_{120}P_{120}$, $N_{160}P_{80}$, $N_{160}P_{120}$, $N_{160}P_{160}$, $N_{120}P_{120}K_{80}$. As a control variant was accepted $N_0P_0K_0$. The results of the study showed, that grain yield has the greatest effect on average for the tested period at fertilization with $N_{80}P_{40}$. The plant height, the number of grains per spike and the weight of the grains per spike showed the highest values under the influence of $N_{160}P_{120}$. The length spike is affected equally by fertilization with N_{160} and $N_{160}P_{120}$. The analysis reveals positive and proven correlations were found between all yield components. The strongest relationship was observed between length spike and number of grain per spike (0.973***).*

Key words: *components of yield, durum wheat, grain yield, mineral fertilization.*

INTRODUCTION

Durum wheat is one of the most important crops in the world. Sardana (2000) reports that durum wheat is consumed by 35% of the world's population. Globally, most consumption is in Europe, South America and the United States (Sall et al., 2019). Filling the nutritional need and large number of the world's population depends on durum wheat (Abbass et al., 2020). Demand for wheat is projected to continue to grow over to coming decades, particularly, in the developing world to feed an increasing population (Desta and Almayehu, 2020). Durum wheat is a traditional crop in Bulgaria (Petrova, 2007). It is mainly used for the production of pasta.

Agricultural production is a dynamic system influenced by multiple factors of different nature (Stoyanov, 2020). Fertilization is one of the most practices in crop production (Jakšić et al., 2021). Nitrogen (N) is the most limiting nutrient for cereal crops (Frija and Annabi, 2020). Currently, the anthropogenic N fixation rate has increasing to 210 Tg per year (Zhang et al., 2021). However, Guerrero et al. (2021) emphasize that plant response to N is limited to a threshold; N fertilization above this level does not increase crop yield any further. Nevertheless, farmers tend to use more mineral and organic N fertilizers than biologically necessary to ensure the highest possible yield (Leslie et al., 2017). Phosphorus is the essential plant nutrient which plays major role for achieving the maximum agricultural production (Arshad et al., 2016). Indeed, the greater part of P remains in insoluble form in soil and, hence, unavailable for the plant (Cherchali et al., 2019). This leads to the use of excessive amounts of phosphorus fertilizers.

Potassium fertilizers are usually considered in third place - after nitrogen and phosphorus. However, many farmers neglect the need for durum wheat from K. Duncan et al. (2018) conclude that improved soil P and K availability has the potential to increase grain yield and improve the efficiency of N fertilizer use.

The above gives us reason to believe that fertilization is not yet developing in the right direction. The aim of our study was to investigate the effect of different fertilizer rates (alone) and different combinations of them on the productivity of durum wheat.

MATERIALS AND METHODS

The experiment was set up in 1966 at the Field Crops Institute, Chirpan, Bulgaria, as a stationary fertilizer trial. The data present

2014/2019 and Progress variety. The trial was conducted by the randomized complete block design in four replications in two-field crop system rotation of durum wheat and cotton (Stefanova-Dobreva & Muhova, 2020). Each plot was 10 m^2.

Four rates of N and P fertilizers were included in the study – alone: 0, 40, 80, 120 and 180 kg ha; and the following combinations – $N_{80}P_{40}$, $N_{80}P_{80}$, $N_{80}P_{120}$, $N_{80}P_{180}$, $N_{120}P_{80}$, $N_{120}P_{120}$, $N_{180}P_{80}$, $N_{180}P_{120}$, $N_{180}P_{180}$. In the experimental design there was a variant with K fertilizer – $N_{120}P_{120}K_{80}$. It is used as a nitrogen fertilizer ammonium nitrate, triple superphosphate was used as the phosphorus fertilizer, and as a potassium fertilizer – potassium sulfate.

The type of soil is Pellic Vertisols (Vp.). The humus content for the layer 0-20 cm is very high – 3.85% (Table 1).

Table 1. Humus content, assessment of humus stock, total nitrogen

Depth, cm	Humus, %	Humus stock in the layer 0-100 cm, t/da	Assessment of the humus stock in degree	Total N, %	$CaCO_3$, %
0-20	3.85	13.86	high	0.20	0.00
20-40	2.80	10.08	high	0.13	0.25
40-60	2.20	6.48	middle	0.10	2.25
60-80	1.95	4.50	low	0.07	4.56
80-100	1.90	3.24	low	0.04	4.56

Its depth in the profile is relatively homogeneous, decreasing in depth from 2.80% to 1.9% in the layer 80-100 cm. The salt content is negligible, which indicates that the soils are well drained and there is no danger of salinization or negative impact on crops. The amount of total carbonates does not exceed 5% in the deep soil horizons and there is no manifestation of chlorosis.

In the studied periods there is a different degree of change in the amount of precipitation and temperature sums (Table 2). During the period 2013/14, 2014/15 and 2018/19 higher temperature amounts were reported, respectively 290.8 °C, 254.4 °C and 245.9 °C than the average for a multi-year period. In 2015/16 and 2017/18 the temperature sums were, respectively, 520.7°C and 427.0 °C higher than in the period 1928/13. Different in terms of temperature is the period 2016/17, in which the temperature sum is 1,843.5 °C or 166.2 °C lower than the climatic average for the long term.

Regarding precipitation, it can be noted that the data for the period 2013/14, 2016/17 and 2018/19 show the amount of precipitation around the norm - 420.8 mm, 375.2 mm and 358.5 mm, during the periods 2014-2015 and 2017-2018 is respectively by 183.1 mm and 66.6 mm more, and in 2015-2016 it was 71.6 mm less.

Abbreviations: GY – grain yield; PH – plant height; LS – length spike; NGS – number of grain per spike; GWS – grain weight per spike.

Table 2. Temperature sum and rainfall during the durum wheat vegetation for the period 2014/2019 and over a multi-year period

Year	Mount								Σ
	XI	XII	I	II	III	IV	V	VI	
Temperature sum, Σ°C									
1928-13	215.9	61.1	-6.2	49.4	188.9	357.9	511.5	630.7	2,009.7
2013/14	275,3	3,1	95,0	160,8	278,7	369,5	510,0	608,1	2,300,5
2014/15	227.2	138.0	74.9	96.0	192.7	340.4	586.0	608.9	2,264.1
2015/16	299.3	115.1	-8.7	233.6	273.5	439.8	498.0	679.8	2,530.4
2016/17	201.7	26.2	-160.7	-46.5	289.2	355.7	513.7	664.2	1,843.5
2017/18	244.9	125.6	65.2	97.8	200.5	471.0	584.8	646.9	2,436.7
2018/19	225.3	20.7	53.8	113.1	292.6	335.2	533.4	681.5	2,255.6
Rainfall, mm									
1928-13	47.3	54.0	44.3	37.7	37.0	45.2	64.1	65.4	395.0
2013/14	49.8	8.6	47.1	1.3	105.7	83.6	99.3	25.4	420.8
2014/15	36.9	14.3	50.3	61.7	134.9	15.1	58.8	78.1	578.1
2015/16	50.2	1.3	73.9	28.3	53.1	26.6	75.0	15.0	323.4
2016/17	47.7	5.9	80.1	23.8	51.3	22.6	59.5	84.3	375.2
2017/18	48.2	38.9	23.3	109.0	83.4	8.7	62.2	87.9	461.6
2018/19	82.3	23.5	28.9	24.5	3.3	51.4	21.4	123.2	358.5

RESULTS AND DISCUSSIONS

According to Table 3, on average for the test period, durum wheat yield of 2,117.4 kg/ha without fertilization. When the mineral fertilization from the independently applied N was included, all tested rates have a confirmed statistical influence. The highest increase was fertilization with 120 kg N ha. This variation exceeds the control by 56.2%. However, the difference with the lower rate (N_{80}) was only 0.8%. The same trend was reported by Tedone et al. (2018). However, the results of our study differ from those of Panayotova & Kostadinova (2015). The authors report that the application of N_{80} leads to an increase in GY by 25-29%, N_{120} by 40-43%, and N_{180} by 45-46%.

Application of P results in a decrease of GY. Three of the tested rates showed lower values compared to the control, as follows: P_{40} by 11.0%, P_{80} by 14.9% and P_{180} by 12.5%. Only the norm of 120 kg P ha showed a slight increase, but the difference of 3.0% remained outside the statistical reliability. The results obtained are contrary to the statement of Nesme et al. (2014) that P levels always strongly influence yield.

Combined NP fertilization had the greatest effect on GY. Average test period the rate of $N_{80}P_{40}$ showed the best results, increasing the values by 64.5% above the control. It is important to note that the highest grain yield was obtained at the lowest NP combination. Panayotova, Kostadinova & Manolov (2018) reported similar results at the same fertilization rates. Analysis of the variance showed a medium degree of influence (P=1%) when fertilizing with $N_{120}P_{120}K_{80}$.

Plant height (Table 3) ranged from 74.6 to 102.6 cm. As expected, the lowest plants were reported from the non-fertilizing variant. From the independent application of fertilizers, the greatest effect was nitrogen fertilization at a rate of 120 kg/ha. This variant exceeds the control by 35.5%. Chipsa et al. (2017) observed a similar trend, reporting that as the nitrogen rate increases, plant height also increases. Desta & Almayehu (2020) also confirm our results. The authors reported that the higher plants have been measured at the highest N rate. Only the rate of 40 kg/ha remained from the independent application of P with confirmed statistical impact. Highest plants were observed at fertilization $N_{180}P_{120}$. Under this variant, the plants were 37.5% high than the control plants.

Table 3. Grain yield (kg ha) and plant height (cm) average for the period

Fertilization rate		GY, kg/ha	% of control	PH, cm	% of control
Control		2,117.4	100.0	74.6	100.0
N_{40}		2,643.5*	124.9	92.4***	123.9
N_{80}		3,289.4***	155.4	98.4***	131.9
N_{120}		3,307.7***	156.2	101.1***	135.5
N_{180}		2,997.7***	141.6	100.3***	134.5
P_{40}		1,885.4^{ns}	89.0	81.6*	109.4
P_{80}		1,801.4^{ns}	85.1	79.6^{ns}	106.7
P_{120}		2,181.2^{ns}	103.0	79.0^{ns}	105.9
P_{180}		1,853.0^{ns}	87.5	80.0^{ns}	107.2
$N_{80}P_{40}$		**3,482.8*** **	**164.5**	99.0***	132.7
$N_{80}P_{80}$		3,426.2***	161.8	96.3***	129.1
$N_{80}P_{120}$		3,375.2***	159.4	96.0***	128.7
$N_{80}P_{180}$		3,217.4***	152.0	96.7***	129.6
$N_{120}P_{80}$		3,457.8***	163.3	99.9***	133.9
$N_{120}P_{120}$		3,407.0***	160.9	98.2***	131.6
$N_{180}P_{80}$		3,322.4***	156.9	99.3***	133.1
$N_{180}P_{120}$		3,107.7***	146.8	**102.6*** **	**137.5**
$N_{180}P_{180}$		3,124.8***	147.6	99.0***	132.7
$N_{120}P_{120}K_{80}$		2,891.2**	136.6	99.2***	133.0
LSD	*5%*	*459.4*	*21.7*	*6.4*	*8.6*
	1%	*608.6*	*28.7*	*8.5*	*11.4*
	0.1%	*786.7*	*37.2*	*10.9*	*14.6*

ns - no significant; *, **, ***significant at P = 5%, P = 1% and P = 0.1%

The analysis of variance averaged over the test period showed a high degree of confidence in the length spike (Table 4). The shortest spike was reported in the control – 5.3 cm. This trait two types of fertilization have the strongest and equal influence – N_{180} and $N_{180}P_{120}$. In both fertilization rates, a 58.5% longer spike than the control was reported. This result gives grounds to report that the additional imported P fertilizer is unjustified.

The number of grains per spike varies from 25.2 to 43.2, on average for the test period (Table 4). The lowest values were reported from the control. Fertilization with $N_{180}P_{120}$ resulted in the highest NGS, with the value being 71.4% above the control. Of all the studied variants with unproven impact, the self-application of P at a rate of 40 kg/ha. The positive effect of mineral fertilization in LS and NGS has been confirmed by many researchers (Esaulko et ai., 2015; Litke et al., 2017; Chibsa et al., 2017).

The results of the dispersion analysis for grain weight per spike, on average for the test period, were similar in terms of the significant effect of mineral fertilization of LS and NGS (table 4). The lightest grains showed the variant without applied mineral fertilizer. The best results and with 98.47% heavier grains than the control was the treatment with $N_{180}P_{120}$. With this trait the influence of P fertilizer was proved statistically for all studied rates. Ibragimov & Mirzaev (2016) confirm that mineral fertilization has a strong effect on GWS.

Table 4. Length spike (cm), number of grain per spike and grain weight per spike (g) average for the period

Fertilization rate		LS, cm	% of control	NGS	% of control	GWS, g	% of control
Control		5.3	100.0	25.2	100.0	1.31	100.00
N_{40}		7.2***	135.9	35.3***	140.1	2.07***	158.02
N_{80}		7.7***	145.3	38.7***	153.6	2.35***	179.39
N_{120}		8.2***	154.7	39.8***	157.9	2.33***	177.86
N_{180}		**8.4*****	**158.5**	42.6***	169.1	2.44***	186.26
P_{40}		5.8^{ns}	109.4	26.5^{ns}	105.2	1.70*	129.77
P_{80}		6.2**	117.0	32.4**	128.6	1.83**	139.70
P_{120}		6.2**	117.0	31.4**	124.6	1.72*	131.30
P_{180}		6.1*	115.1	31.7**	125.8	1.83**	139.70
$N_{80}P_{40}$		7.0***	132.1	35.5***	140.9	2.00***	152.67
$N_{80}P_{80}$		7.4***	139.6	35.3***	140.1	1.95***	148.86
$N_{80}P_{120}$		7.6***	143.4	37.8***	150.0	2.10***	160.31
$N_{80}P_{180}$		7.7***	145.3	38.0***	150.8	2.32***	177.10
$N_{120}P_{80}$		8.0***	150.9	39.2***	155.6	2.35***	179.39
$N_{120}P_{120}$		7.8***	147.2	38.3***	152.0	2.20***	167.94
$N_{180}P_{80}$		8.1***	152.8	41.0***	162.7	2.36***	180.15
$N_{180}P_{120}$		**8.4*****	**158.5**	**43.2*****	**171.4**	**2.60*****	**198.47**
$N_{180}P_{180}$		8.3***	156.6	42.7***	169.5	2.32***	177.10
$N_{120}P_{120}K_{80}$		7.9***	149.1	42.2***	167.5	2.42***	184.73
LSD	*5%*	*0.7*	*13.2*	*4.7*	*18.7*	*0.33*	*25.19*
	1%	*0.9*	*17.0*	*6.2*	*24.6*	*0.44*	*33.59*
	0.1%	*1.1*	*20.8*	*8.1*	*32.1*	*0.57*	*43.51*

ns - no significant; *, **, ***significant at P = 5%, P = 1% and P = 0.1%

Table 5 shows the correlation coefficients of the studied traits. The analysis reveals that on average over a 6-year period, positive and proven correlations were found between all yield components.

Table 5. Correlation coefficients between the studied traits

	GY	*PH*	*LS*	*NGS*	*GWS*
GY	1				
PH	0.908***	1			
LS	0.818***	0.952***	1		
NGS	0.733***	0.905***	**0.973*****	1	
GWS	0.698***	0.907***	0.955***	0.961***	1

*** significant at 0.01% level of probability

The strongest relationship was observed between LS and NGS (0.973***). This result is confirmed by the study of Bilgin et al. (2008). On the other hand, Moosavi et al. (2020) reported an unproven correlation between the two traits in bread wheat. The lowest was the relationship between GY and GWS (0.698***). GY showed the strongest connection with PH (0.908***). The study of Turan (2018) reaches the same strong connection between the two traits.

CONCLUSIONS

Based on the results obtained, it can be concluded that the yield has been affected to the greatest extent by fertilization with $N_{80}P_{40}$. The greatest impact on plant height was reported by the variant $N_{180}P_{120}$. The fertilization with N_{180} and $N_{180}P_{120}$ had the same effect on the length of spike. Combined fertilization $N_{180}P_{120}$ had the greatest impact on the number and weight of grains per spike. Correlation analysis showed a strong and proven relationship between all studied traits, but the highest correlation coefficient was found between the length spike and the number of grains per spike.

REFERENCES

Abbass, D.M., Al-Layla, M.G., Al-Hamdani, Z.B. (2020). Estimation of heritability and expect genetic improvement and expected in Durum Wheat (*Triticum durum* Desf.). *Journal of University of Shanghai for Science and Technology, 22*(10), 2192–2200.

Arshad, M., Adnan, M., Ahmed, Sh., Khan, A.K., Ali, I., Ali, M., Ali, A., Khan, A., Kamal, M.A., Gul, F. and Khan, M.A. (2016). Integrated effect of phosphorus and zinc on wheat crop. *American-Eurasian J. Agric. And Environ. Sci., 16*(3), 455–459.

Bilgin, O., Korkut, K.Z., Başer, I., Dağlioğlu, O., Öztürk, I., Kahraman, T. (2008). Determination of variability between grain yield and yield components of durum wheat varieties (*Triticum durum* Desf.) in Thrace region. *Journal of Tekirdag Agricultural Faculty, 5*(2), 101–109.

Cherchali, A., Boukhelata, N., kaci, Y., Abrous-Belbachir, O., Djebbar, R. (2019). Isolation and identification of a phosphate-solubilizing *Paenibaccilus polymyxa* strain GOL 0202 from durum wheat (*Triticum durum* Desf.) rhizosphere and its effect on some seedling morphophysiological parameters. *Biocatalysis and Agricultural Biotechnology, 19*. 101087 from https://doi.org/10.1016/j.bcab.2019.101087

Chipsa, T., Gebrekidan, H. Debele, T. (2017). Effect of rate and time of nitrogen fertilizer application on durum wheat (*Triticum turgidum* Var. L. *Durum*) grown on Vertisol of Bale highland, southeastern Ethiopia. *Am J. Res. Commun., 5*(1), 39–56.

Desta, B.T., Almayehu, Y. (2020). Optimizing blended (NPSB) and N fertilizer rates for the productivity of Durum Wheat (*Triticum turgidum* L. var. durum) in Central Nighlands of Ethiopia. *Soil and Crop Science* from htpps://doi.org/10.1080/23311932.2020.1766733

Duncan, E.G., O'Sullivan, C.A., Roper, M.M., Biggs, J.S., Peoples, M.B. (2018). Influence of co-application of nitrogen with phosphorus, potassium and Sulphur on the apparent efficiency of nitrogen fetiliser use, grain yield and protein content of wheat: Review. *Field Crop Research, 226*. 56–65. https://doi.org/10.1016/j.fcr.2018.07.010

Esaulko, A.N., Salenko, E.A., Sigida, M.S., Korostylev, S.A., Golosnoy, E.V. (2015). Agrochemical principles of targeting winter wheat yield on leached Chernozem of the Stavropol elevation. *Biosciences Biotechnology Research Asia, 12*(1), 301–309.

Frija, A., Annabi, M. (2020). Effect of tillage, previous crops, and N fertilization on agronomic and economic performances of durum wheat (*Triticum durum* Desf.) under rainfed semi-arid environment. *Agronomy, 10*. 1161 doi:10.3390/agronomy10081161

Guerrero, A., De Neve, S., Mouazen, A.M. (2021). Data fusion approach for map-based variable-rate nitrogen fertilization in barley and wheat. *Soil and Tillage Research, 205*. 104789 from https://doi.org/10.1016/j.still.2020.104789

Jakšić, S., Ninkov, J., Milić, S., Vasin, J., Banjac, D., Jakšić, D., Živanov, M. (2021). The state of soil organic carbon in vineyards as affected by soil type and fertilization strategies (Tri Morave Region, Serbia). *Agronomy, 11*. 9 from https://dx.doi.org/10.3390/agronomy11010009

Ibragimov, N.M., Mirzaev, L.A. (2016). Effect of mineral fertilizer rates on yield components and grain yield of irrigated winter wheat in the South of Karakalpakstan. The *Way of science 10*(32), 36–39.

Leslie, J.E., Weersink, A., Yang, W., Fox, G., 2017. Actual versus environmentally recommended fertilizer application rates: Implications for water quality and policy. *Agriculture, Ecosystems and Environment, 240*. 109–120. In: Guerrero, A., De Neve, S. and Mouazen, A.M., 2021. Data fusion approach for map-based variable-rate nitrogen fertilization in barley and wheat. Soil and Tillage Research, vol. 205, 104789 from https://doi.org/10.1016/j.still.2020.104789

Litke, L, Gaile, Z., Ruža, A. (2017). Nitrogen fertilizer influence on winter wheat yield and yield components depending on soil tillage and forecrop. *Research for Rural Development, 2*. 54–61.

Moosavi, S.S., Nazari, M., Chaichi, M., Goharrizi, K.J. (2020). The most effective yield-components associated with increasing yield of wheat (*Triticum aestivum* L.) under terminal drought stress conditions. *Desert, 25*(2), 139–146.

Nesme, T., Colomb, B., Hinsinger, P., Watson, C.A. (2014). Soil phosphorus management in organic cropping systems: from current practices to avenues for a more efficient use of P resources. Organic farming, prototype for sustainable agriculture. *Spring Netherlands*, Dordecht, 23–45.

Panayotova, G., Kostadinova, S., Manolov, I. (2018). Mineral balances of nitrogen and phosphorus in cotton-durum wheat crop rotation depends on the fertilization system. *53rd Croatian & 13th International Symposium on Agriculture*. February 18 - 23, 2018, Vodice, Croatia, 333–337.

Panayotova, G., Kostadinova, S. (2015). Nitrogen fertilization of durum wheat varieties. *Bulgarian Journal of Agricultural Science, 21*(3), 596–601.

Petrova, I., 2007. End-use Quality of Bulgarian Durum Wheat. Bulgarian *Journal of Agricultural Science, 13*. 161–169.

Stefanova-Dobreva, St., Muhova, A. (2020). Effect of low rates of mineral fertilizers on the productivity of durum wheat (*Triticum durum* Desf.). *Scientific Papers. Series A. Agronomy, Vol. LXIII*(1),. 134–141. http://agronomyjournal.usamv.ro/ pdf/2020/issue_1/Art18.pdf

Stoyanov, H. (2020). Effect of the environmental conditions and the crop density on economically important indices of Bulgarian triticale cultivars (x *Triticosecale* Witmm.). *Journal of Mountain Agriculture on the Balkans, 23*(3), 115–141.

Sall, A.T., Chairi, T., Leggese, W., Seid-Ahmed, K., Ortiz, R., Ginkel, M. and Bassi, F.M., 2019. Durum Wheat (*Triticum durum* Desf.): Origin, Cultivation and Potential Expansion in Sub-Saharan Africa. *Agronomy 2019, 9*. 263.

Sardana, V. (2000). Export potential of durum wheat. Agricultural tribune, online edition. *Chandigarh, India*.

Tedone, L., Ali, S.A., Verdini, L., De Mastro, G. (2018). Nitrogen management strategy for optimizing agronomic and environmental performance of rainfed durum wheat under Mediterranean climate. *Journal of Cleaner Production, 172*. 2058–2074. from https://doi.org/10.1016/j.clepro.2017.11.215

Turan, F. (2018). Evolution of seed yield of durum wheat under drought stress and determining correlation among some yield components using path coefficient analysis from https://dx.doi.org/10.22458/urj.v10i1.2023

Zhang, M., Zhang, X., Zhang, L., Zeng, L., Liu, Y., Wang, X., He, P., Li, P., Liang, G., Zhou, W. and Ai, Ch. (2021). The stronger impact of inorganic nitrogen fertilization on soil bacterial community than organic fertilization in short-term conditions. *Geoderma, 382.* https://doi.org/10.1016/j.geoderma.2020.114752