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EFFECTIVENESS OF UAN FERTILISATION WITH POTASSIUM THIOSULPHATE IN PEPPER AND TOMATO CULTIVATION

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ABSTRACT

The European Commission proposed the European Green Deal, aiming to reduce plant nutrient losses by at least 50% while preventing soil fertility deterioration and reducing fertiliser use by at least 20% by 2030. Of particular importance for environmental reasons is the reduction of nitrogen fertilisation rates. UAN is a highly concentrated nitrogen fertiliser in an aqueous solution of nitrate and urea ammonium nitrate. This study evaluated the effectiveness of fertilisation in pepper and tomato cultivation using UAN mixtures with potassi um thiosulphate in proportions selected based on a model pot experiment. The field experiment was conducted from 2019 to 2020 at the Felin Experimental Farm of the University of Life Sciences in Lublin. The test plants were sweet peppers of the Balta F_1 cultivar *(Capsicum annuum* L.) and tomatoes of the Mirsini cultivar (*Lycopersicon esculentum* Mill.). The experiment included the following variable factors: nitrogen dose (2 levels: N_1 – optimum nitrogen rate and N_2 – nitrogen rate reduced by 25% from the optimum dose) and fertiliser composition (2 levels: pure UAN – $N : K_0 : S_0$, UAN with potassium thiosulphate – $N : K_1 : S_1$). Taking into account the pepper yield and the accumulation of nitrogen, phosphorus, potassium and sulphur in the fruit, the most favourable fertilisation combination was the combination of an optimal nitrogen dose (170 kg N ha^{-1}) with potassium thiosulphate. The reduction of the nitrogen dose and the treatment of fertilisation with a dose of 128 kg N ha^{-1} with potassium thiosulphate favoured an increase in the vitamin C content of the pepper fruit. The effect of nitrogen dose on tomato fruit yield was modified by the year of the study. Thus, in tomatoes, it is possible to reduce the nitrogen dose depending on weather conditions. At the same time, the addition of potassium thiosulphate is recommended, which has a beneficial effect on the fruit's potassium, phosphorus and sulphur and vitamin C content. There was no significant effect of varying nitrogen and potassium fertilisation on the dry matter content of pepper and tomato fruit, while the effect on calcium, magnesium and extract content was inconclusive.

Keywords: *Capsicum annuum*, *Lycopersicon esculentum*, yield, chemical composition, nutritional value, vegetables

INTRODUCTION

The European Commission proposed the European Green Deal, aiming to reduce plant nutrient losses by at least 50% while preventing soil fertility deterioration and reducing fertiliser use by at least 20% by 2030 [Artyszak and Gozdowski 2020]. Of particular importance for environmental reasons is the reduction

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of nitrogen fertilisation doses. Nitrogen is an essential ingredient for plant growth, so to high restrictions on using nitrogen fertilisers may risk reducing yields.

UAN (urea-ammonium nitrate solution) is increasingly being used to fertilise horticultural and especially agricultural crops. UAN is a highly concentrated nitrogen fertiliser in an aqueous solution of nitrate and urea ammonium nitrate. It is in liquid form, which speeds up the uptake of nitrogen by plants. UAN acts quickly and over time, so plants have a constant nitrogen supply during the growing season. Fertiliser is a solution for ammonium nitrate and urea. In favourable proportions, it contains nitrogen in three forms (ammonium, nitrate and amide). The fertiliser may be applied presowing and top dressing. Applying UAN using a sprayer (coarse droplet tip – droplet diameter over 400 μm) or pouring technique is recommended. Spraying or pouring the fertiliser allows the fertiliser to be evenly distributed. Fine droplet spraying can burn the plants [Bros 2001]. UAN has a high fertiliser efficiency during drought, which has become particularly important in recent years. UAN solution is produced in three N concentrations (28% N, 30% N, 32% N) and is adapted to different transport and storage temperatures. The producer of UAN® fertiliser is Grupa Azoty [https://nawozy.eu/nawozy/azotowe/rsm.html].

Within the framework of a sustainable agriculture system implementing the principles of good agricultural practice (Code of the Best Agriculture Practice) in line with IFA/IFMA declarations, it is recommended, among other things, that highly condensed liquid fertilisers with compositions tailored to the individual nutritional needs of the crops grown be more widely implemented [Górecki 2002]. In line with these trends, UAN has been enriched with sulphur and is offered in the form of two fertilisers: UAN®S – urea ammonium nitrate solution with sulphur, obtained based on urea ammonium nitrate solution and urea solution with ammonium sulphate (contains 26% nitrogen and 3% sulphur); UAN®S 28-5 – obtained based on urea ammonium nitrate solution and ammonium thiosulphate (https://nawozy.eu/nawozy/azotowe-z-siarka/rsms.html).

As part of Project No. POIR.01.02.00-00-0061/17 "Development of a technology for obtaining potassium thiosulphate with the use of blow gases from sulphuric acid production facilities and multicomponent liquid fertilisers based on it", carried out under research topic 43.6 of the "INNOCHEM" sectoral programme, financed from NCBR funds under Measure 1.2 "Sectoral R&D programmes", Priority Axis I "Support for the conduct of R&D works by enterprises" of the Operational Programme Intelligent Development 2014–2020, (Task No. 3) in model studies the optimum N : K (and respectively S) ratio was established for the best efficiency of nitrogen contained in UAN. Experimental research included pot experiments in the first year, which provided the basis for field experiments.

Potassium is among the elements that significantly impact the quality of vegetable and fruit yield [Lester et al. 2010, Mardanluo et al. 2018]. The plant takes up this element rapidly and in large quantities as a monovalent cation supplied to the soil or substrate with potassium fertilisers [Isidora et al. 2008, Pitura et al. 2012]. According to Golcz et al. [2012], "the type of potassium fertiliser used plays an important role in plant nutrition. The supply of potassium to plants in the form of chloride, sulphate or nitrate modifies the chemical composition of plants because the anions accompanying potassium have different functions".

This study evaluated the effectiveness of fertilisation in pepper and tomato cultivation of UAN mixtures with potassium thiosulphate in proportions selected based on a model pot experiment. Tomato and pepper are the primary vegetables of the *Solanaceae* family present in our diet, whose yield and nutritional value are of particular importance to humans.

MATERIAL AND METHODS

The pot experiments were conducted in 2018 provided the basis for field experiments, which started in 2019 and were repeated in the same scheme in 2020. The field experiment was conducted from 2019 to 2020 at the Felin Experimental Farm of the University of Life Sciences in Lublin. The test plants were sweet peppers of the Balta F_1 cultivar (*Capsicum annuum* L.) and tomatoes of the Mirsini cultivar (*Lycopersicon esculentum* Mill.).

The following basic parameters were determined in order to characterise the soils: the granulometric composition – by the laser method [PN-R-04032], the pH value in 1 mol KCl – by the potentiometric method [ISO 10390], total N – by a modified Kjeldahl method [ISO 11261], the contents of available phosphorus [PN-R-04023] and potassium [PN-R-04022] by the Egner–Riehm method, and sulphur – by the nephelometric method according to the Bardsley and Lancaster's formula [Boratyński et al. 1975]. The soil on which the field experiment was conducted, according to the classification of soils [IUSS 2022] and agronomic categories, is classified into the group: dust, sub–group: silt loam. Granulometric composition: sand fraction – range 2.0–0.05 mm – 21.21% (of which: 2.0–1.0 mm – 0.00%; 1.0–0.5 mm – 0.00%; 0.5–0.25 mm – 0.00%; 0.25–0.10 mm – 1.61%; 0.10–0.05 mm – 19.60%), dust fraction – range 0.05–0.002 mm – 73.32% (including: 0.05–0.02 mm – 42.96%; 0.02–0.002 mm – 30.36%) and silt fraction – range below 0.002 mm – 5.47%.

In 2019, the soil on which the experiment was conducted was characterised by a slightly acid reaction, a total nitrogen content of 0.90 g N kg^{-1} DM and a low abundance in assimilable forms of phosphorus, a medium abundance in assimilable potassium and a very high abundance in assimilable sulphur. In 2020, the soil reaction was also slightly acidic; the content of total nitrogen was, on average, 0.78 g N kg^{-1} DM, the abundance in assimilable forms of phosphorus and potassium was at a medium level, while the abundance in assimilable sulphur was high (Tab. 1). The weather data during the 2019–2020 crop-growing season are shown in Table 2.

The experiment included the following variable factors: nitrogen rate (2 levels: N_1 – optimum nitrogen rate and N_2 – nitrogen rate reduced by 25% from the optimum rate) and fertiliser composition (2 levels: pure UAN – N : K_0 : S_0, UAN with potassium thiosulphate – N : K_1 : S_1).

Phosphorus fertilisation was applied before planting. Fertilisers based on UAN and potassium thiosulphate were applied according to the recommendations established based on the pot experiment performed in 2018. Fertiliser with a ratio of N : K : S, like 1 : 1.1 : 0.7, was applied to cultivate both species. The doses of fertiliser components and their application dates were the same in both years of the experiment (Tabs 3–5).

Before the experiment, the necessary cultivation treatments was carried out and experimental plots of 2.0 m × 1.2 m (area 2.4 m^2) were delineated. The experiment was performed in 3 replicates. Peppers were grown in a plastic tunnel, and tomatoes were planted in the field.

Sweet peppers of the Balta F_1 cultivar were grown from seedlings produced in the vegetation hall of the Institute of Horticultural Production of the University of Life Sciences in Lublin from sowing carried out annually on 18 March. Plants were transplanted into pots on 5–6 April. Seedlings were planted into the ground in a plastic tunnel on 20.05.2019 and 19.05.2020 at a spacing of 40 × 40 cm (10 plants per plot). During the growing season, the plants were fed three times with 0.01% Pionier Mikro Plus (B 0,2%, Cu – 0,1%, Fe 2,0%, Mn 0,8%, Mo 0,05%, Zn 0,3%), and protective treatments were applied in 2019 against pests: spraying with Pirimor WG 500 (pirymicarb) and Mospilan 20 SP (acetamiprid) and against fungal diseases: Topsin M 500 SC (thiophanate-methyl) and Signum 33 WG (boscalid + pyraclostrobin), while in 2020: preparations Mospilan 20 SP and Vertigo 018 EC (abamectin) and against fungal diseases: Switch 62.5 WG (cyprodinil + fludioxonil) and Scorpion 325 SC (azoxystrobin). Drip irrigation was used in pepper and tomato cultivation. Weeds were removed from the plots manually and with the help of rakes.

Pepper fruits were harvested as the fruits matured at the usable maturity stage – in 2019 on six dates: 23.07., 31.07., 4.09., 11.09., 20.09., 9.10., and in 2020 on four dates: 25.08., 2.09., 16.09., 6.10. Immediately after harvesting the peppers, the weight of individu-

Table 1. Soil chemical properties prior to the establishment of the 2019–2020 experiments in the 0–20 cm soil layer

Year	pH	Content			
		g N kg^{-1} DM	mg P kg^{-1} DM	mg K kg^{-1} DM	mg S-SO_4 kg^{-1} DM
2019	5.80	0.90	23.35	148.0	41.06
2020	5.60	0.78	50.51	157.5	38.54

al fruits per plant and the total number of fruits per 1 plant were determined.

Tomato of the Mirsini cultivar was also grown from seedlings, with sowing carried out on 2.04.2019 and 1.04.2020. The seedling was planted in the field on 22.05.2019 and 18.05.2020 at a spacing of 40 × 40 cm (10 plants per plot). During vegetation, plant feeding was carried out three times with Pionier Mikro Plus (0.01%) and protective treatments were also applied: in 2019 – spraying with Mospilan 20 SP against pests, Topsin M 500 SC 0.15% and Signum 33 WG against fungal diseases; in 2020 – preparation Mospilan 20 SP and against fungal diseases: Topsin M 500 SC, Signum 33 WG, Switch 62.5 WG, Scorpion 325 SC, Guaranteed 500 SC.

Tomato fruit was harvested at the usable maturity stage on nine dates in 2019: 27.07., 2.08., 5.08., 9.08., 16.08., 22.08., 29.08., 5.09., 12.09., and in 2020: 13.08., 20.08., 26.08., 3.09., 9.09., 15.09., 24.09., 05.10., 09.10. Immediately after the tomato harvest, the weight of individual fruits per plant and the total number of fruits per 1 plant were determined. Based on the results obtained during pepper and tomato harvest, the yield of plants per unit area was converted.

Plant material samples were taken for chemical analyses at the functional maturity stage. The chemical composition was determined in the plant material obtained, including the content of the essential mineral elements – total nitrogen, phosphorus, potassium, magnesium, calcium and sulphate (VI) sulphur, as well as the content of vitamin C and extract.

Methodology for chemical analyses of plant material: nitrogen and protein content – by Kjeldahl method; phosphorus content – by vanadium-molybdenum method, potassium; magnesium and calcium content – by ASA method after mineralisation of plant material in concentrated sulphuric acid (H_2SO_4) with the addition of perhydrol (H_2O_2); sulphate(VI) content – by nephelometric method after extraction of plant material with 2% CH_3COOH with addition of activated carbon [Grzesiuk 1968]; vitamin C content – by HPLC method [PN-EN 14130:2003]; extract content (%) – using RQ Easy refractometer and Merck test strips.

The results obtained were statistically verified with the ANOVA module (for factorial systems) of the STATISTICA 9.0 PL (StatSoft, Inc.). NIR values were determined using Tukey's HSD test with a significance level of $\alpha = 0.05$ and $\alpha = 0.01$.

RESULTS AND DISCUSSION

The growth and development of pepper and tomato differed in the subsequent years of the study and were modified mainly by weather conditions (Tab. 2). The onset of pepper flowering was similar in both study years (9.06.2019, 10.06.2020), but the onset of fruit set in 2020 was recorded much later than in the previous year (13.06.2019, 30.06.2020). In 2019, the first

Table 2. Mean air temperatures and amount of precipitation in ES Felin during the experiment in 2019–2020 (by Laboratory of Agrometeorology UP Lublin)

	Year	Month and decade															
		V			VI			VII			VIII			IX			X
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1
Average decade temperature (°C)	2019	9.8	13.8	16.2	20.3	23.4	20.7	17.6	18.0	22.3	19.6	20.0	21.1	17.9	13.1	12.6	8.6
	2020	11.7	11.4	12.0	21.4	24.6	23.3	19.6	18.2	19.8	21.9	20.0	19.4				
Mean monthly for 1951–2005			13.0			16.2			17.8			17.1			12.6		7.8
Amount of precipitation (mm)	2019	0.3	72.2	20.0	3.8	5.2	28.1	17.0	2.8	18.1	36.6	61.8	3.9	14.2	4.6	33.1	28.7
	2020	21.0	5.7	77.6	37.0	41.4	89.7	11.9	16.6	0.2	4.6	4.3	36.2				
Mean monthly for 1951–2005			57.7			65.7			83.5			68.6			51.6		40.1

Table 3. Specification of fertilisers used in the field experiment with pepper and tomato

Name of fertiliser	Fertiliser characteristics
UAN	Urea ammonium nitrate solution Liquid fertiliser: N total – 32% (m/m) $N-NH_4$ – 8% (m/m) $N-NO_3$ – 8% (m/m) $N-NH_2$ – 16% (m/m)
SUPER FOS DAR 40	P_2O_5 soluble in mineral acids (total): 41.2% P_2O_5 soluble in neutral ammonium citrate solution: 31.3% P_2O_5 water-soluble: 28.9% Water-soluble CaO 13.1%
Fertiliser based on UAN 32 and potassium thiosulphate:	
N : K : S – 1 : 1.1 : 0.7	Liquid fertiliser: Total N – 9.05% (m/m) Potassium as K_2O – 9.95% (m/m) Sulphur as S – 6.73% (m/m) Sulphur as SO_3 – 16.81 % (m/m) Density – 1,244 g cm^{-3}

Table 4. Application rates and timing of fertilisers for peppers

$N : K_0 : S_0$		$N : K_0 : S_0$	
N_1 dose (kg ha^{-1})	170	N_2 dose (kg ha^{-1})	128
P dose (kg ha^{-1})	88	P dose (kg ha^{-1})	88
K dose (kg ha^{-1})	0	K dose (kg ha^{-1})	0
$N : K_0 : S_0$ ratio	1 : 0 : 0	$N:K_0:S_0$ ratio	1:0:0
$N : K_1 : S_1$ fertiliser		$N : K_1 : S_1$ fertiliser	
N_1 dose (kg ha^{-1})	170	N_2 dose (kg ha^{-1})	128
P dose (kg ha^{-1})	88	P dose (kg ha^{-1})	88
K dose (kg ha^{-1})	155	K dose (kg ha^{-1})	117
$N : K_1 : S_1$ ratio:	1 : 1.1 : 0.7	$N : K_1 : S_1$ ratio:	1 : 1.1 : 0.7
Timing of fertiliser applications			
	N and K	30% pre-sowing, 30% in 3–4 weeks after planting, twice 20% at 2–3 week intervals	
	P	pre-sowing	

harvest of ripe pepper fruit was made on 23.07.2019; in 2020, it was not until 25.08.2020. The start of tomato flowering in 2019 was on 7.06.2019, and the first green fruit was recorded on 17.06.2019. In 2020, tomatoes started flowering slightly earlier (03.06.2020), but the first green fruit appeared later than the previous year (25.06.2020). In 2019, the first harvest of ripe tomato fruit was made on 27.07.2019; in 2020, it was not until 13.08.2020.

A consequence of the differences in the course of plant vegetation due to the prevailing weather conditions was the yield differences recorded between the

Table 5. Application rates and timing of fertilisers for tomatoes

N : K_0 : S_0		N : K_0 : S_0	
N_1 dose (kg ha^{-1})	150	N_2 dose (kg ha^{-1})	113
P dose (kg ha^{-1})	44	P dose (kg ha^{-1})	44
K dose (kg ha^{-1})	0	K dose (kg ha^{-1})	0
N : K_0 : S_0 ratio	1 : 0 : 0	N : K_0 : S_0 ratio	1 : 0 : 0
N : K_1 : S_1 fertiliser		N : K_1 : S_1 fertiliser	
N_1 dose (kg ha^{-1})	150	N_2 dose (kg ha^{-1})	113
P dose (kg ha^{-1})	44	P dose (kg ha^{-1})	44
K dose (kg ha^{-1})	137	K dose (kg ha^{-1})	103
N : K_1 : S_1 ratio:	1 : 1.1 : 0.7	N : K_1 : S_1 ratio:	1 : 1.1 : 0.7
Timing of fertiliser applications			
	N and K	30% pre-sowing, 30% in 3–4 weeks after planting, twice 20% at 2–3 week intervals	
	P	pre-sowing	

years of the study for both tomato and pepper, despite growing them in a plastic tunnel.

The pepper fruit yield per plant for the two years averaged 2.03 kg, and in 2020 (1.55 kg), it was significantly lower than in 2019 (2.48 kg) – as in Table 6. In a study by Michałojć and Dzida [2012], an average of 14.3 fruits with a total weight of 1.431 kg were harvested from 1 plant of sweet red pepper Red Knight F_1 grown in a greenhouse, while in other studies, pepper Rebeka F_1 gave a marketable yield of 1.43–1.89 kg [Michałojć and Horodko 2006]. The fruit yield of tomatoes in subsequent years of the study developed differently from that of pepper, even though they belong to the same botanical family (*Solanaceae*). In 2020, tomato yield per plant was almost twice as high (8.15 kg) as in 2019 (4.36 kg) – as in Table 7. The start of tomato vegetation in 2019 was under over-watering conditions, which can be explained by a different response to nitrogen fertilisation than in 2020 (Tab. 2). The manufacturer does not recommend the application of UAN after rain. The peppers were grown in a plastic tunnel, so excess rainfall in May was not detrimental. However, the differentiated fertilisation did not significantly affect the total tomato fruit yield harvested per plant. In 2020, a slightly higher yield, contrary to the previous year, was harvested from plants fertilised with a lower dose of nitrogen (113 kg N ha^{-1}) with potassium thiosulphate (8.83 kg) than with the other fertilisation variants (7.72–8.10 kg on average), but these differences were not statistically confirmed. It is confirmed by Kowalska's [1996] study, which noted the lack of effect of fertiliser nitrogen form (urea, ammonium and nitrate) on tomato fruit yield.

According to Golcz et al. [2012], the success of red pepper cultivation depends on many factors, including mineral fertilisation, especially potassium and nitrogen. In a study conducted in pepper cultivation, the dose of nitrogen did not significantly affect fruit yield when evaluated independently of potassium fertilisation; however, significantly, the highest pepper yield per plant (2.27 kg) was obtained with N fertilisation in the treatment at 170 kg N ha^{-1} with potassium thiosulphate, and the lowest (1.74 kg) with pure UAN fertilisation (without potassium) at a dose of 170 kg N ha^{-1}. This relationship occurred in both years of the study.

Similar relationships were noted in the assessment of yield per unit area. The total pepper fruit yield from all crops averaged 8.36 kg m^{-2} for the two years and was significantly lower in 2020 (6.44 kg m^{-2}) than in 2019 (10.28 kg m^{-2}) – as in Table 6. The average marketable fruit yield of red peppers Cyklon, grown in a plastic tunnel from two years of experiments was 2.15 kg m^{-2} [Golcz et al. 2012]. In the present study, differentiated fertilisation did not significantly affect the yield of

Table 6. Influence of nitrogen dose and fertiliser composition on selected pepper fruit yield traits from all harvests in 2019–2020

Specification	Fertiliser content (B)	Year (C)								
		2019			2020			Mean		
		N dose kg ha^{-1} (A)								
		170	128	$\bar{x}$	170	128	$\bar{x}$	170	128	$\bar{x}$
Pepper fruit yield per plant (kg)	N : K_0 : S_0	2.18	2.62	2.40	1.30	1.57	1.44	1.74	2.10	1.92
	N : K_1 : S_1	2.73	2.39	2.56	1.81	1.51	1.66	2.27	1.95	2.11
	$\bar{x}$	2.46	2.51	2.48	1.55	1.54	1.55	2.01	2.03	2.02
$LSD_{,05}$		A – ns	B – ns	A × B – 0.53	A – ns	B – 0.20	A × B – 0.38	A – ns	B – ns	A × B – 0.365
								A × C – ns	B × C – ns	C – 0.197
The unit weight of pepper fruit (g)	N : K_0 : S_0	228.38	243.22	235.80	208.55	221.09	214.82	218.47	232.16	225.31
	N : K_1 : S_1	249.38	254.20	251.79	214.15	230.62	222.38	231.77	242.41	237.09
	$\bar{x}$	238.88	248.71	243.80	211.35	225.86	218.60	225.12	237.29	231.20
$LSD_{0.05}$		A – ns	B – 13.85	A × B – ns	A – 14.11	B – ns	A × B – ns	A – 9.782	B – 9.782	A × B – ns
								A × C – ns	B × C – ns	C – 9.782
Number of pepper fruit per plant	N : K_0 : S_0	9.63	10.80	10.21	6.30	7.20	6.75	7.97	9.00	8.48
	N : K_1 : S_1	11.00	9.47	10.23	8.63	6.67	7.65	9.82	8.07	8.94
	$\bar{x}$	10.32	10.13	10.22	7.47	6.93	7.20	8.90	8.53	8.71
$LSD_{0.05}$		A – ns	B – ns	A × B – 1.34	A – ns	B – ns	A×B – 1.84	A – ns	B – ns	A × B – 1.471
								A × C – ns	B × C – ns	C – 0.793
Total pepper fruit yield (kg m^{-2})	N : K_0 : S_0	9.11	10.92	10.01	5.42	6.55	5.98	7.27	8.74	8.00
	N : K_1 : S_1	11.39	9.69	10.54	7.54	6.27	6.91	9.47	7.98	8.73
	$\bar{x}$	10.25	10.31	10.28	6.48	6.41	6.44	8.37	8.36	8.36
$LSD_{0.05}$		A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – 1.880

$\bar{x}$ – mean; ns – no significant differences

peppers. However, in both years of the study, a slightly higher yield was obtained when peppers were grown in the fertilisation treatment of 170 kg N ha^{-1} with potassium thiosulphate (on average 9.47 kg m^{-2}), and the smallest without the addition of potassium thiosulphate (7.27 kg m^{-2}). In a study by Golcz et al. [2012], higher levels of N and K fertilisation significantly increased total red pepper fruit yield by an average of 18%. Nurzyński [1994] reported no significant differences in tomato, pepper, cucumber, lettuce or kale yields when different forms of potassium fertiliser were applied.

The total tomato fruit yield from all harvests in 2020 averaged 33.96 kg m^{-2}, almost double that of 2019 (18.17 kg m^{-2}) – as in Table 7. Significantly higher tomato yield in 2020 was obtained in the trial fertilised with a lower nitrogen rate (113 kg N ha^{-1}) than with 150 kg N ha^{-1} and slightly higher when fertilised with the combination of 113 kg N ha^{-1} with potassium thiosulphate (average 36.77 kg m^{-2}). However, the effect of differential fertilisation on tomato yield was insignificant in the year-independent evaluation. Ddamulira et al. [2019] found that lower

Table 7. Influence of nitrogen dose and fertiliser composition on selected tomato fruit yield traits from all harvests in 2019–2020

Specification	Fertiliser content (B)	Year (C)								
		2019			2020			Mean		
		N dose kg ha^{-1} (A)								
		150	113	$\bar{x}$	150	113	$\bar{x}$	150	113	$\bar{x}$
Tomato fruit yield per plant (kg)	N : K_0 : S_0	4.37	4.32	4.34	7.96	8.10	8.03	6.17	6.21	6.19
	N : K_1 : S_1	4.44	4.32	4.38	7.72	8.83	8.27	6.08	6.58	6.33
	$\bar{x}$	4.40	4.32	4.36	7.84	8.46	8.15	6.12	6.39	6.26
$LSD_{0.05}$		A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – 0.513
The unit weight of tomato fruit (g)	N : K_0 : S_0	156.59	151.86	154.23	203.27	203.99	203.63	179.93	177.93	178.93
	N : K_1 :S_1	156.43	153.08	154.76	204.38	213.58	208.98	180.41	183.33	181.87
	$\bar{x}$	156.51	152.47	154.49	203.83	208.79	206.31	180.17	180.63	180.40
$LSD_{0.05}$		A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – 6.277
Number of tomato fruit per plant	N : K_0 : S_0	28.23	28.10	28.16	39.13	39.30	39.22	33.68	33.70	33.69
	N : K_1 : S_1	28.50	28.37	28.44	38.00	41.03	39.52	33.25	34.70	33.98
	$\bar{x}$	28.37	28.23	28.30	38.57	40.17	39.37	33.47	34.20	33.84
$LSD_{0.05}$		A – ns	B – ns	A×B – ns	A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – 2.474
Total tomato fruit yield (kg m^{-2})	N : K_0 : S_0	18.21	17.97	18.09	33.15	33.74	33.45	25.68	25.86	25.77
	N : K_1 : S_1	18.49	18.00	18.24	32.15	36.77	34.46	25.32	27.39	26.35
	$\bar{x}$	18.35	17.98	18.17	32.65	35.26	33.96	25.50	26.62	26.07
$LSD_{0.05}$		A – ns	B – ns	A × B – ns	A – 2.46	B – ns	A × B – ns	A – ns	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – 1.515

$\bar{x}$ – mean; ns – no significant differences

fertiliser rates negatively affected the growth and yield of cherry tomatoes. They showed that tomatoes responded significantly to nitrogen and potassium fertiliser application by increasing plant height and yield. In a study by Gupta and Sengar [2000], increasing nitrogen and potassium application increased tomato yield and fruit weight. Many authors believe that increasing potassium fertilisation levels can increase tomato fruit yield [Al-Karaki 2000, Yurtseven 2005]. Significant increase in tomato yield with increasing potassium fertiliser rates was reported by Javaria et al. [2012]. According to Ehsan et al. [2010], despite high K levels in the soil, tomato requirements for higher yield could not be met from the native source; hence, the addition of potassium is necessary through fertilisation. Yang et al. [2018] showed that nitrogen fertilisation significantly affected tomato fruit yield, followed by potassium fertilisation and plant density. They found a significant effect of interaction between plant density and fertiliser rate. In a study by Breś and Ruprik [2006], the amount of nitrogen and potassium and the nitrogen/potassium ratio in the nutrient solution significantly affected the yield of small-fruited greenhouse tomato cultivars. Depending on the cultivar, the optimum N : K ratio was in the range of 1 : 1.3–1 : 1.4, while no apparent effect of the applied nutrient solutions on the nutritional value of the cultivated tomato cultivars was found.

The unit weight of pepper fruit averaged 231.20 g from all harvests from the two years of the study and was significantly higher in 2019 (243.80 g) than in 2020 (218.60 g) – as in Table 6. Fruit with a higher weight (by 12.17 g on average) was obtained using a lower nitrogen rate (128 kg N ha^{-1}). This relationship occurred in both years of the study, but significant differences were recorded only in 2020. Adding thiosulphate to UAN significantly increased the unit fruit weight (by 11.78 g on average). In both years of the study, fruit with the highest weight were harvested from plants fertilised with a lower nitrogen dose (128 kg N ha^{-1}) with potassium thiosulphate, and with the lowest weight from plants fertilised with a higher nitrogen dose (170 kg N ha^{-1}) without potassium fertilisation, although these differences were not statistically significant. In a study by Johnson and Decoteau [1996], increasing the potassium rate in pepper cultivation increased the fruit's biomass, number and weight. El-Bassiony et al. [2010], in the cultivation of sweet pepper 'Kalifornia' showed that increasing the dose of potassium fertilisation to 200 kg had the most significant effect, favourably affecting plant growth, foliage and the highest total yield, as well as fruit size and unit weight. The beneficial effect of potassium fertilisation on pepper fruit yield and quality parameters, including fruit length/diameter ratio, fruit dry matter content, and vitamin C content, was confirmed in a study by Mardanluo et al. [2018].

The varying fertilisation did not significantly affect the unit weight of tomato fruit. The average weight of 1 tomato fruit from all crops and years was 180.40 g and was significantly higher in 2020 (206.31 g) than in 2019 (154.49 g) – as in Table 7. The number of fruits harvested per plant in 2020 averaged 39.37 fruits and was 11.07 higher than in the previous year (28.30 fruits), but there was also no statistically significant effect of varying fertilisation on the total number of tomato fruits harvested per plant. In contrast, in the study by Javaria et al. [2012], the number of tomato fruits per plant increased significantly with increasing potassium fertilisation levels. In a study by Samiullah and Khan [2003], the addition of potassium doubled the number of fruits per 1 plant compared to a crop without potassium fertilisation. Javaria et al. [2012] found that the average tomato fruit weight increased significantly with the addition of potassium compared to no K in fertiliser. Similarly, Padema and Ocala [1999] showed that increased levels of potassium fertilisation led to a significant increase in fruit weight. In their study, unlike tomatoes, pepper responded to varying fertilisation. In both years of the study and the year-independent evaluation, most fruits were harvested from plants grown in the fertilisation combination of 170 kg N ha^{-1} with the addition of potassium thiosulphate (on average 9.82 fruits). On average, 8.71 pieces of fruit were harvested per pepper plant for the two years, with significantly more in 2019 (10.22 fruits) than in 2020 (10.22 fruits) – as in Table 6. The beneficial effect of potassium fertilisation on pepper fruit yield per plant, fruit number and fruit weight was shown by Botella et al. [2017]. Also, in the study by Golcz et al. [2012], higher doses of nitrogen and potassium fertilisation increased the number of pepper fruits. On the other hand, Ortas [2013], investigating the effect of nitrogen and potassium fertilisers, found that pepper and tomato plants responded significantly ($P < 0.01$) to nitrogen fertilisation (100 and 200 kg N ha^{-1}) by increasing plant height, yield and nutrient content, while potassium fertilisers had less effect on these parameters.

The chemical composition of pepper and tomato fruit was assessed at the stage of usable maturity. In pepper fruit, on average, the following were determined: 18.03 g N kg^{-1} DM, 3.36 g P kg^{-1} DM, 30.66 g K kg^{-1} DM, 1.27 g Mg kg^{-1} DM, 2.35 g Ca kg^{-1} DM, 0.72 g S-SO_4 kg^{-1} DM (Tab. 8). The peppers accumulated an average of 7.75% dry matter in the fruit. Depending on the fertilisation combination and the year of the study, this content ranged from 6.56 to 9.14% and was significantly higher in 2019 than in 2020, while differentiated fertilisation did not affect this value. In a study by Kowalska and Sady [2012], the dry matter content of pepper fruit ranged from 6.79 to 10.75%. In a study by Zalewska-Korona et al. [2013], the dry matter content in tomato fruit averaged 5.95% and took values ranging from 5.34% to 6.61%, depending on the cultivar. In the study, they determined an average of 16.48 g N kg^{-1} DM, 5.17 g P kg^{-1} DM, 35.66 g K kg^{-1} DM, 1.54 g Mg kg^{-1} DM, 2.38 g Ca kg^{-1} DM, 0.67 g S-SO_4 kg^{-1} DM (Tab. 9). The dry matter content of tomato fruit in the successive years of the study ranged from 4.98 to 6.55% on average. Different fertilisation did not significantly affect this trait. More dry matter was determined in tomatoes harvested in 2019 than in 2020. In a study by Kowalska [1996], the form of fertiliser nitrogen had no significant effect on tomato fruit's dry matter, sugars and ascorbic acid content. A beneficial effect of potassium fertilisation on the dry matter content of pepper fruit was reported by Mardanluo et al. [2018].

Nitrogen fertilisation at a higher (optimum) dose in both years of the study significantly increased the total nitrogen content in pepper fruit (on average by 1.24 g N kg^{-1} DM) and tomato fruit (on average by 1.21 g N kg^{-1} DM) compared to the application of a lower nitrogen dose (Tabs 7 and 8). In an evaluation independent of the year of study, adding potassium thiosulphate to UAN increased the N content of pepper fruit (Tab. 8). Significantly, the highest amount of total nitrogen was determined in pepper fruits grown in the combination fertilised with a dose of 170 kg N ha^{-1} with potassium thiosulphate (average 19.65 g N kg^{-1} DM), and the lowest – with a lower nitrogen dose (128 kg N ha^{-1}) with potassium thiosulphate (average 16.85 g N kg^{-1} DM). This relationship occurred in both years of the study. In tomatoes, the response was different (Tab. 9). Irrespective of the nitrogen dose, the addition of potassium thiosulphate decreased the nitrogen content in tomato fruit by 1.13 g N kg^{-1} DM on average. Irrespective of the year of the study, the highest nitrogen was determined in tomato fruit fertilised with pure UAN without the addition of potassium thiosulphate (17.83 g N kg^{-1} DM on average). According to Zawartka et al. [1996], the total N content in tomato fruit did not significantly depend on the amount of potassium used in fertilisation.

Different doses of nitrogen fertilisation did not significantly affect the phosphorus content in pepper fruits, which, depending on the year of the study, ranged from 2.64 to 4.65 g P kg^{-1} DM on average (Tab. 8). On the other hand, in tomato fruits, irrespective of the study year, significantly more phosphorus (on average by 0.72 g P kg^{-1} DM) was determined after fertilisation with the optimal dose of nitrogen (150 kg N ha^{-1}) than with the reduced dose (113 kg N ha^{-1}) – as in Table 8. More phosphorus was determined in pepper fruit (on average by 0.20 g P kg^{-1} DM) and tomato (on average by 0.18 g P kg^{-1} DM) fertilised with UAN with potassium thiosulphate than pure UAN. This relationship occurred in both years of the study, but only in 2020 were the differences statistically significant. The highest amount of phosphorus on average for the two years (5.57 g P kg^{-1} DM) was determined in tomato fruit fertilised with the higher nitrogen dose (150 kg N ha^{-1}) with potassium thiosulphate, and the least (4.66) – with the lower dose of nitrogen (113 kg N ha^{-1}) without thiosulphate. In pepper fruits, the highest amount of phosphorus was also determined after fertilisation with the higher dose of nitrogen (170 kg N ha^{-1}) with potassium thiosulphate (on average 3.88 g P kg^{-1} DM). In 2020, pepper and tomato fruit contained more phosphorus than in 2019.

In 2020, tomatoes accumulated more potassium in fruit, whereas there was significantly less potassium in pepper fruit in 2020 than in 2019. In 2020, more potassium (on average by 1.45 g K kg^{-1} DM) was determined in pepper fruit fertilised with the optimal nitrogen dose (170 kg N ha^{-1}) than with the reduced one (Tab. 8). However, in an evaluation independent of the year of the study, the effect of nitrogen dose on K content in fruit was not significant. The addition of potassium thiosulphate significantly increased the potassium content of the fruit (on average by 1.56 g K kg^{-1} DM) compared to those obtained from a crop fertilised with pure UAN. In a study by Golcz et al. [2008], the varying levels of nitrogen fertilisation had no effect on the nutritional status of pepper plants with this macronutrient, while the potassium content of the leaves was slightly higher at higher fertilisation levels. The increase in potassium content in pepper fruits after potassium fertilisation is confirmed by the study of Shehata et al. [2019]. In our study, the effect of varying fertilisation on potassium accumulation in tomato fruit was similar to that in pepper (Tab. 8). There was no significant effect of nitrogen dose on potassium accumulation in fruit, while more potassium (on average by 1.46 g K kg^{-1} DM) was determined in tomato fruit fertilised with UAN supplemented with potassium thiosulphate. These correlations occurred in both years of the study. In a study [Golcz and Kozik 2004], pepper fruits contained more potassium with increasing potassium levels in the substrate irrespective of the harvest stage.

The calcium content of pepper fruit in subsequent years of the study ranged from 1.09 to 3.95 g Ca kg^{-1} DM on average, with the effect of fertilisation on Ca

Table 8. Effect of nitrogen dose and fertiliser composition on dry matter content (%) and selected components in pepper fruit (g kg^{-1} DM) in 2019–2020

Specification	Fertiliser content (B)	Year (C)								
		2019			2020			Mean		
		N dose kg ha^{-1} (A)								
		170	128	$\bar{x}$	170	128	$\bar{x}$	170	128	$\bar{x}$
Dry matter content in pepper fruit (%)	N : K_0 : S_0	9.14	8.89	9.02	6.92	6.56	6.74	8.03	7.73	7.88
	N : K_1 : S_1	8.52	8.64	8.58	6.73	6.56	6.64	7.63	7.60	7.61
	$\bar{x}$	8.83	8.77	8.80	6.82	6.56	6.69	7.83	7.67	7.75
$LSD_{0.05}$		A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – 0.585
Total N content in pepper fruit (g kg^{-1} DM)	N : K_0 : S_0	18.20	19.41	18.81	17.08	16.52	16.80	17.64	17.97	17.81
	N : K_1 : S_1	20.63	17.83	19.23	18.67	15.87	17.27	19.65	16.85	18.25
	$\bar{x}$	19.42	18.62	19.02	17.87	16.19	17.03	18.65	17.41	18.03
$LSD_{0.01}$		A – 0.663	B – ns	A × B – 1.227	A – 0.797	B – ns	A × B – 1.475	A – 0.452	B – 0.452	A × B – 0.803
								A × C – 0.803	B × C – ns	C – 0.452
P content in pepper fruits (g kg^{-1} DM)	N : K_0 : S_0	2.94	2.99	2.97	2.64	4.44	3.54	2.79	3.72	3.26
	N : K_1 : S_1	3.11	3.16	3.14	4.65	2.89	3.77	3.88	3.03	3.46
	$\bar{x}$	3.03	3.08	3.06	3.65	3.66	3.66	3.34	3.37	3.36
$LSD_{0.01}$		A – ns	B – ns	A × B – ns	A – ns	B – 0.157	A × B – ns	A – ns	B – 0.135	A × B – 0.241
								A×C – ns	B×C – ns	C – 0.135
K content in pepper fruits (g kg^{-1} DM)	N : K_0 : S_0	33.35	34.15	33.75	26.95	25.05	26.00	30.15	29.60	29.88
	N : K_1 : S_1	33.60	34.25	33.93	29.45	28.45	28.95	31.53	31.35	31.44
	$\bar{x}$	33.48	34.20	33.84	28.20	26.75	27.48	30.84	30.48	30.66
$LSD_{0.01}$		A – ns	B – ns	A × B – ns	A – 1.31	B – 1.31	A × B – ns	A – ns	B – 0.697	A × B – ns
								A × C – 1.240	B × C – 1.240	C – 0.697
Ca content in pepper fruits (g kg^{-1} DM)	N : K_0 : S_0	3.95	3.18	3.57	1.11	1.09	1.10	2.53	2.14	2.34
	N : K_1 : S_1	3.91	2.31	3.11	1.30	1.90	1.60	2.61	2.11	2.36
	$\bar{x}$	3.93	2.75	3.34	1.20	1.50	1.35	2.57	2.13	2.35
$LSD_{0.01}$		A – 0.357	B – 0.357	A×B – 0.662	A – 0.048	B – 0.048	A × B – 0.088	A – 0.157	B – ns	A × B – ns
								A × C – 0.279	B × C – 0.279	C – 0.157
Mg content in pepper fruits (g kg^{-1} DM)	N : K : S	1.61	1.39	1.50	1.04	1.04	1.04	1.33	1.22	1.27
	N : K_1 : S_1	1.48	1.44	1.46	1.11	1.03	1.07	1.30	1.24	1.27
	$\bar{x}$	1.55	1.42	1.48	1.08	1.04	1.06	1.32	1.23	1.27
$LSD_{0.01}$		A – ns	B – ns	A × B – ns	A – 0.025	B – ns	A × B – 0.047	A – 0.112	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – 0.112
S (VI) content in pepper fruits (g kg^{-1} DM)	N : K_0 : S_0	0.82	0.66	0.74	0.53	0.53	0.53	0.68	0.60	0.64
	N : K_1 : S_1	0.92	0.67	0.80	0.84	0.74	0.79	0.88	0.71	0.80
	$\bar{x}$	0.87	0.66	0.77	0.69	0.64	0.66	0.78	0.65	0.72
$LSD_{0.01}$		A – 0.180	B – ns	A × B – ns	A – 0.027	B – 0.027	A × B – 0.051	A – 0.079	B – ns	A × B – 0.141
								A × C – 0.141	B × C – ns	C – 0.079

$\bar{x}$ – mean; ns – no significant differences

content being ambiguous (Tab. 8). In 2020, inversely to the previous year, more Ca was determined in pepper fruits fertilised with 128 kg N ha^{-1} than with 170 kg N ha^{-1}, while the addition of potassium thiosulphate resulted in a significant increase in calcium content in pepper fruits. In an evaluation independent of the year of the study, more calcium was determined after fertilisation with a dose of 128 kg N ha^{-1} than with 170 kg N ha^{-1}, and the addition of potassium thiosulphate to UAN had no significant effect. In contrast, Mardanluo et al. [2018] reported a reduction in calcium content in peppers with higher levels of K in the nutrient solution. The calcium content of tomato fruit in successive years of the study ranged on average from 1.39 to 3.54 g Ca kg^{-1} DM (Tab. 9). There was no significant effect of the nitrogen dose or the addition of potassium thiosulphate on this trait. Regardless of the year of the study, the most negligible Ca was determined in tomato fruit fertilised with UAN without the addition of potassium thiosulphate.

The magnesium content of pepper fruits took average values of 1.03 to 1.61 g Mg kg^{-1} DM, which was lower in 2020 than in 2019 (Tab. 8). In tomato fruit, Mg content took average values of 1.37 to 1.86 g Mg kg^{-1} DM and was higher in 2020 than in 2019 (Tab. 9). More magnesium was in pepper and tomato fruits fertilised with the optimal nitrogen dose (170 kg N ha^{-1}) than the reduced dose (128 kg N ha^{-1}). The addition of potassium thiosulphate to UAN did not affect the Mg content in pepper fruit, while the highest Mg content in tomato fruit was determined after fertilisation with UAN without potassium thiosulphate (1.65 g Mg kg^{-1} DM). In a study by Jarosz [2006], the type of potassium fertilisation did not significantly affect the chemical composition of tomato fruit.

The effect of differentiated fertilisation on sulphur content in pepper and tomato fruit in both years of the study was analogous (Tabs 8 and 9). Fertilisation with a dose of 170 kg N ha^{-1} increased the sulphate(VI) sulphur content in pepper fruit compared to a dose of 128 kg N ha^{-1}, which did not affect sulphur accumulation in tomato fruit. Adding potassium thiosulphate to UAN increased the sulphur content in the fruit of both studied species (pepper and tomato). In tomato cultivation, this relationship occurred at both nitrogen doses. On average, for two years, tomato fruit fertilised with UAN with potassium thiosulphate contained 0.16 g more sulphate (VI) sulphur than those fertilised with pure UAN (Tab. 9). In pepper fruits, the highest amount of sulphate (VI) sulphur was determined after cultivation in the fertilisation combination of 170 kg N ha^{-1} with potassium thiosulphate (on average 0.88 g S-SO_4 kg^{-1} DM) and the least with pure UAN (0.60 g) – as in Table 8. This relationship occurred in both years of the study. In Kowalska's [2004] study, increasing the sulphate concentration in the nutrient solution increased total sulphur and sulphate content in all tomato parts analysed, regardless of the developmental stage. Breś and Ruprik [2007] found that varying amounts of nitrogen and potassium and the ratios between these elements in the nutrient solution (within the studied range) did not significantly affect the nutritional status of small-fruited tomato cultivars concerning macro and micronutrients.

The content of vitamin C and extract in pepper fruits did not differ significantly between the years of the study. On average, sweet pepper fruits contained 160.37 mg of vitamin C per 100 g of FW (Tab. 10). In a study by Golcz and Kozik [2004], the vitamin C content in sweet pepper was 156–316 mg and varied depending on the nitrogen fertiliser type, potassium fertilisation level and weather conditions. Michałojć and Horodko [2006] determined an average of 131.25 to 141.25 mg of vitamin C per 100 g of FW in the fruits of the pepper Rubin F_1 and showed no apparent effect of differentiated fertilisation on the content of vitamin C and sugars in pepper fruits. In their study, more vitamin C was determined in pepper fruits fertilised with a lower dose of nitrogen (128 kg N ha^{-1}) than with 170 kg N ha^{-1}. This relationship occurred in both years of the study. In contrast, the variation in nitrogen dose did not significantly affect the vitamin C content of tomato fruit in both years of the study, which ranged from 23.13 to 27.47 mg/100 g FW and was higher in 2019 (Tab. 11). In the study by Zalewska-Korona et al. [2013], the average vitamin C content of tomato fruit was 16.02 mg/100 g and ranged from 12.82 to 20.51 mg/100 g, depending on the cultivar. In the study conducted, the addition of potassium thiosulphate to UAN increased the vitamin C content of tomato fruit in both years. On average, for two years, the difference was significant and amounted to

Table 9. Effect of nitrogen dose and fertiliser composition on dry matter content (%) and selected components in tomato fruit (g kg^{-1} DM) in 2019–2020

Specification	Fertiliser content (B)	Year (C)								
		2019			2020			Mean		
		N dose kg ha^{-1} (A)								
		150	113	$\bar{x}$	150	113	$\bar{x}$	150	113	$\bar{x}$
Dry matter content in tomato fruit (%)	N : K_0 : S_0	6.30	6.55	6.42	5.32	5.47	5.39	5.81	6.01	5.91
	N : K_1 : S_1	6.48	6.50	6.49	4.98	5.39	5.19	5.73	5.95	5.84
	$\bar{x}$	6.39	6.53	6.46	5.15	5.43	5.29	5.77	5.98	5.88
$LSD_{0.05}$		A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – 0.339
Total N content in tomato fruit (g kg^{-1} DM)	N : K_0 : S_0	16.05	15.68	15.87	19.60	16.80	18.20	17.83	16.24	17.04
	N : K_1 : S_1	16.33	13.81	15.07	16.33	17.17	16.75	16.33	15.49	15.91
	$\bar{x}$	16.19	14.75	15.47	17.97	16.99	17.48	17.08	15.87	16.48
$LSD_{0.01}$		A – 0.541	B – 0.541	A × B – 1.00	A – 0.750	B – 0.750	A × B – 1.387	A – 0.403	B – 0.403	A × B – 0.716
								A × C – ns	B × C – 0.716	C – 0.403
P content in tomato fruits (g kg^{-1} DM)	N : K_0 : S_0	5.12	5.26	5.19	5.84	4.06	4.95	5.48	4.66	5.07
	N : K_1 : S_1	4.54	4.70	4.62	6.59	5.17	5.88	5.57	4.94	5.25
	$\bar{x}$	4.83	4.98	4.91	6.21	4.62	5.42	5.52	4.80	5.17
$LSD_{0.01}$		A – ns	B – ns	A × B – 0.377	A – 0.149	B – 0.149	A × B – 0.275	A – 0.110	B – 0.110	A × B – 0.195
								A×C – 0.195	B×C – 0.195	C – 0.110
K content in tomato fruits (g kg^{-1} DM)	N : K_0 : S_0	33.33	33.93	33.63	37.03	35.42	36.22	35.18	34.68	34.93
	N : K_1 : S_1	34.57	34.97	34.77	38.35	37.67	38.01	36.46	36.32	36.39
	$\bar{x}$	33.95	34.45	34.20	37.69	36.54	37.12	35.82	35.50	35.66
$LSD_{0.01}$		A – ns	B – 1.130	A × B – ns	A – 1.026	B – 1.026	A × B – ns	A – ns	B – 0.742	A × B – ns
								A × C – 1.319	B × C – ns	0.742
Ca content in tomato fruits (g kg^{-1} DM)	N : K_0 : S_0	2.83	3.54	3.19	1.55	1.39	1.47	2.19	2.47	2.33
	N : K_1 : S_1	3.54	3.10	3.32	1.49	1.54	1.52	2.52	2.32	2.42
	$\bar{x}$	3.19	3.32	3.26	1.52	1.46	1.49	2.36	2.39	2.38
$LSD_{0.01}$		A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – 0.163	A – ns	B – ns	A × B – 0.526
								A × C – ns	B × C – ns	C – 0.296
Mg content in tomato fruits (g kg^{-1} DM)	N : K : S	1.44	1.46	1.45	1.86	1.46	1.66	1.65	1.46	1.56
	N : K_1 : S_1	1.42	1.37	1.40	1.60	1.68	1.64	1.51	1.53	1.52
	$\bar{x}$	1.43	1.42	1.43	1.73	1.57	1.65	1.58	1.50	1.54
$LSD_{0.01}$		A – ns	B – ns	A × B – ns	A – ns	B – ns	A × B – ns	A – 0.078	B – ns	A × B – 0.139
								A × C – 0.139	B × C – ns	C – 0.078
S (VI) content in tomato fruits (g kg^{-1} DM)	N : K_0 : S_0	0.67	0.74	0.71	0.48	0.46	0.47	0.58	0.60	0.59
	N : K_1 : S_1	0.86	0.89	0.88	0.62	0.62	0.62	0.74	0.76	0.75
	$\bar{x}$	0.77	0.82	0.79	0.55	0.54	0.55	0.66	0.68	0.67
$LSD_{0.01}$		A – ns	B – 0.067	A × B – ns	A – ns	B – 0.008	A × B – 0.014	A – 0.029	B – 0.029	A × B – 0.052
								A × C – 0.052	B × C – 0.052	C – 0.029

$\bar{x}$ – mean; ns – no significant differences

Table 10. Influence of nitrogen dose and fertiliser composition on vitamin C and extract content of pepper fruits in 2019–2020

Specifiction	Fertiliser content (B)	Year (C)								
		2019			2020			Mean		
		N dose kg ha^{-1} (A)								
		170	128	$\bar{x}$	170	128	$\bar{x}$	170	128	$\bar{x}$
Vit. C (mg 100^{-1} g FW)	N : K_0 : S_0	146.08	161.25	153.67	165.17	164.83	165.00	155.63	163.04	159.34
	N : K_1 : S_1	157.42	166.17	161.80	152.33	169.67	161.00	154.88	167.92	161.40
	$\bar{x}$	151.75	163.71	157.73	158.75	167.25	163.00	155.25	165.48	160.37
$LSD_{0.01}$		A – ns	B – ns	A × B – ns	A – 9.01	B – ns	A × B – 15.92	A – 7.642	B – ns	A × B – ns
								A × C – ns	B × C – ns	C – ns
Extract (%)	N : K_0 : S_0	6.25	6.14	6.20	6.25	6.09	6.17	6.25	6.12	6.19
	N : K_1 : S_1	5.53	6.06	5.80	5.93	5.86	5.89	5.73	5.96	5.85
	$\bar{x}$	5.89	6.10	6.00	6.09	5.97	6.03	5.99	6.04	6.02
$LSD_{0.01}$		A – 0.157	B – 0.157	A × B – 0.269	A – ns	B – 0.122	A × B – ns	A – ns	B – 0.106	A × B – 0.181
								A × C – 0.181	B × C – ns	C – ns

$\bar{x}$ – mean; ns – no significant differences

Table 11. Influence of nitrogen dose and fertiliser composition on vitamin C and extract content of tomato fruits in 2019–2020

Specofocation	Fertiliser content (B)	Year (C)								
		2019			2020			Mean		
		N dose kg ha^{-1} (A)								
		150	113	$\bar{x}$	150	113	$\bar{x}$	150	113	$\bar{x}$
Vit. C (mg 100^{-1} g FW)	N : K_0 : S_0	24.58	26.25	25.42	23.13	24.73	23.93	23.86	25.49	24.68
	N : K_1 : S_1	27.42	27.47	27.45	24.93	24.58	24.76	26.18	26.03	26.11
	$\bar{x}$	26.00	26.86	26.43	24.03	24.66	24.35	25.02	25.76	25.39
$LSD_{0.01}$		A – ns	B – ns	A × B – 1.941	A – ns	B – 0.903	A × B – 1.596	A – ns	B – 1.017	A × B – 1.770
								A × C – ns	B × C – ns	C – 1.017
Extract (%)	N : K_0 : S_0	4.75	5.03	4.89	4.42	4.48	4.45	4.59	4.76	4.67
	N : K_1 : S_1	4.91	4.93	4.92	4.39	4.41	4.40	4.65	4.67	4.66
	$\bar{x}$	4.83	4.98	4.91	4.40	4.45	4.43	4.62	4.72	4.67
$LSD_{0.01}$		A – 0.127	B – ns	A × B – 0.219	A – ns	B – ns	A × B – ns	A – 0.082	B – ns	A × B – 0.141
								A × C – ns	B × C – ns	C – 0.082

$\bar{x}$ – mean; ns – no significant differences

1.43 mg/100 g p.m. Significantly, the least vitamin C was determined in tomato fruit fertilised with pure UAN without thiosulphate (analogously in both years of the study). On the other hand, in the case of pepper, in 2020, the highest amount of vitamin C was determined in the fruit of plants fertilised with the combination of 128 kg N ha^{-1} with potassium thiosulphate (average 169.67 mg–100 g^{-1} św.m.) An analogous trend occurred in 2019. Jarosz [2006] found no significant effect of potassium fertilisation on the content of dry matter, vitamin C and total sugars in tomato fruit. In contrast, El-Bassiony et al. [2010], in the cultivation of California sweet pepper, showed that increasing the potassium fertilisation rate to 200 kg had a beneficial effect on vitamin C accumulation in the fruit.

The extract content in pepper fruit for the two years averaged 6.02% (Tab. 10) and in tomato fruit 4.67% DM (Tab. 11), with more extract in tomato fruit in 2019 than in 2020. The nitrogen dose did not significantly affect the extract content in pepper fruit. However, in 2019, more extract was determined in pepper fruit fertilised with a dose of 128 kg N ha^{-1} than after fertilisation with 170 kg N ha^{-1}, and this trend also occurred in 2020. Also, in tomato cultivation, significantly more extract was contained in the fruit of plants fertilised with a lower nitrogen dose (113 kg N ha^{-1}). Adding potassium thiosulphate to UAN significantly reduced the extract content of pepper fruit (by 0.34% on average). The effect of nitrogen dose on the extract content of pepper fruit was inconclusive. On average, for the two years, the highest extract content was determined in pepper fruits fertilised with pure UAN without adding potassium thiosulphate (6.25%). Adding potassium thiosulphate to UAN did not affect extract accumulation in tomato fruit. In a study by Zalewska-Korona et al. [2013], the extract content of tomatoes averaged 4.38%, taking values from 387 to 4.90%, depending on the cultivar. Breś and Ruprik [2006] found no apparent effect of the applied nutrient solutions of the N : K ratio on the nutritional values of the cultivated tomato varieties. The N : K ratio in nutrient solutions used by different authors is very wide, often depending on the growth stage and development of the tomato, and ranges from 1 : 1.05–1 : 1.1 to 1 : 1.87 [Komosa 2000, Kołota and Biesiada 2002].

CONCLUSIONS

1. Taking into account the pepper yield and the accumulation of nitrogen, phosphorus, potassium and sulphur in the fruit, the most favourable fertilisation combination was the combination of an optimal nitrogen dose (170 kg N ha^{-1}) with potassium thiosulphate. The reduction of the nitrogen dose and the combination of fertilisation with a dose of 128 kg N ha^{-1} with potassium thiosulphate favoured an increase in the vitamin C content of the pepper fruit.
2. The effect of nitrogen dose on tomato fruit yield varied by the year of the study. Thus, in tomatoes, it is possible to reduce the nitrogen dose depending on weather conditions. At the same time, the addition of potassium thiosulphate is recommended, which has a beneficial effect on the fruit's potassium, phosphorus and sulphur and vitamin C content.
3. There was no significant effect of varying nitrogen and potassium fertilisation on the dry matter content of pepper and tomato fruit, while the effect on calcium, magnesium and extract content was inconclusive.

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