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Effect of treatment of narcissus bulbs with hydrogen peroxide with silver and fungicides on plant growth and development

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Abstract: The aim of the research was to demonstrate the possibility of using hydrogen peroxide with silver (H_2O_2-Ag^+) and selected fungicides for treating narcissus bulbs and their impact on plant growth and development. In the experiments were used compounds such as hydrogen peroxide with silver (H_2O_2-Ag^+) and captan (Biszop 80 WG), pyraclostrobin + boscalid (Signum 33 WG) and methyl thiophanate + tetraconazole (Yamato 303 SE) to soak narcissus bulbs before planting for the period of 20 minutes. The research showed that stimulation of growth and development by some of the tested concentrations of H_2O_2-Ag^+ used to treat bulbs was shown with regard to plant height, leaf length, fresh flower weight, dry flower weight, the number of days from taking plants out of cold storage to flowering, the weight of fresh above-ground parts without flowers, the weight of dry above-ground parts without flowers, the diameter of the flowers, the height of the flowers, petals length, the width of the petals and the length of the corolla. In turn, the tested fungicides stimulated the length of leaves, the fresh weight of plants without flowers, and Signum 33 WG and Biszop 80 WG also the dry weight of flowers. No phytotoxicity of hydrogen peroxide with silver and tested fungicides was found for narcissus.

Keywords: bulb soaking; compounds; cooling chamber; narcissus; new technology production; rooting

The effect of the tested substances used to treat bulbs on the growth and development of narcissus is little explained. Unverified scientific reports show that hydrogen peroxide provides growth benefits beyond controlling plant infection and plant stress (Webber et. al. 2007). In turn, Ahmad et al. (2017) showed that hydrogen peroxide (H_2O_2) used for maise seed dressing or foliar spraying improved

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the physiological, biochemical and morphological characteristics as well as grain yield and quality. In addition, the authors observed higher activity of superoxide dismutase, catalase and peroxidase in plants treated with H_2O_2 by seed dressing or foliar spray than in the control. Not only the membrane stability index, relative water content, chlorophyll content, but also the grain yield and grain oil content were improved by using H_2O_2. Seed treatment with H_2O_2 was as effective as foliar application (Ahmad et al. 2017). Also, Bayoumi (2008) showed a positive effect of using H_2O_2 at a concentration of 1.5% for 30 min of bathing pepper fruits before storing them for four weeks. After removing the fruit from the cold store, it was found that the decrease in fruit weight was reduced, their rot was minimised, and the contents of ascorbic acid and the oxidants activity increased (among others). The effect of the tested substances used to treat bulbs on the growth and the development of narcissus is also little explained in the literature, but Li et al. (2007) showed that treatment of cucumber seedlings (*Cucumis sativus* L.) after removal of primary roots with 20–40 mM H_2O_2 with raised the number of adventitious roots, and also the treatment with 10–50 mM H_2O_2 significantly increased the fresh mass of adventitious roots. The obtained results go to show that H_2O_2 might act as a signalling molecule influencing the formation and development of adventitious roots in cucumber.

Gupta et al. (2018) indicated that some reports show the toxic effect of biosynthesised silver nanoparticles (AgNPs) on plant growth and development, in which the induction of oxidative stress was thought to be one of the causative factors. The studies by Gupta et al. (2018) also showed the phytostimulating effect of AgNPs *in vitro* on the seed germination and seedling growth of rice (*Oryza sativa* L.). Each tested concentration of AgNPs (10, 20, 40 ppm) raised the content of chlorophyll *a* and carotenoids and increased the length of seedlings and their biomass. In addition, the exposure to AgNPs noticeably raised the content of chlorophyll *a* and carotenoids. The stimulation of rice seedling growth by AgNPs was additionally supported by the low level of reactive oxygen species (ROS) with reduced lipid peroxidation and H_2O_2 contents in comparison to the control. The increased levels of catalase (CAT), ascorbate peroxidase (APX) and glutathione reductase (GR) activities were noted in all AgNPs-treated seedlings together with enhanced growth.

Literature data on the impact of the use of protection products on crops are often contradictory, depending on the agent used and the species or variety of the plant (Wojdyła 2000). Due to literature reports, we decided to undertake a very important issue in our research – the effect of applied fungicides on the growth and development of narcissus. Tort and Turkyilmaz (2003), using captan to treat pepper seeds (*Capsicum annuum* L.) before sowing, found a reduction in the rate of germination. On the other hand, the tested agent used to spray seedlings increased the content of chlorophyll *a* and *b* in leaves. Similarly, in some *in vitro* tests, the negative effect of captan on both seed germination and pepper growth was demonstrated by Seyhan et al. (2019). On the contrary, Manjunath and Bagyaraj (1984) did not observe any negative impact of captan applied to the soil in low doses of 2.5 μg/g of soil on onion growth.

Pyraclostrobin in concentrations from 0.05% to 1% applied to spray soybean seedlings on the 10^{th} and 20^{th} day after the emergence significantly increased the number of nodules, mass of nodules, root biomass and growth of shoots and leaves, which visibly influenced the yield and its quality (Joshi et al. 2014). In a study Henry et al. (2011), with low disease pressure, soybean sprayed with pyraclostrobin showed an increase in yield by 100 kg/ha and a 3% increase in seed weight was found.

The aim of the research was to demonstrate the possibility of using hydrogen peroxide with silver (H_2O_2-Ag^+) and selected fungicides for treating narcissus bulbs, their impact on the development.

MATERIAL AND METHODS

Experimental design. The experiments were conducted in 2021–2022 at the Horticultural Farm Jacek Wiśniewski Spółka Jawna and the Institute of Horticulture – National Research Institute in Skierniewice. The material and methods used in the present work are similar to those used in earlier research on hyacinth (Wojdyła et al. 2022). Narcissus bulbs were treated with the plant growth stimulator Bisteran (50% hydrogen peroxide + 0.32 g of silver in 1 kg) and the fungicides: Biszop 80 WG (80% captan), Signum 33 WG (67 g of pyraclostrobin in 1 kg + 267 g boscalid in 1 kg) and Yamato 303 SE (233 g thiophanate methyl in 1 L + 70 g tetraconazole in 1 L). Control bulbs were soaked in water.

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Narcissus L. 'Tete-a-Tete' bulbs packed in 3 kg Raschel bags were immersed in the tested agents for 20 min according to the following scheme:

1 – Control (water);
2 – Bisteran 1%;
3 – Bisteran 2%;
4 – Bisteran 3%;
5 – Bisteran 5%;
6 – Bisteran 10%;
7 – Yamato 303 SE 0.5%;
8 – Signum 33 WG 0.5%;
9 – Biszop 80 WG 1%.

For soaking the bulbs in plastic buckets, 10 L of suspensions of preparations were prepared. The bags full of bulbs were taken out, drained in order to get rid of the excess liquid and dried for several minutes. Then, the bulbs were planted in pots with a diameter of 8 cm and a volume of 0.3 L. The substrate consisted of de-acidified raised peat and sand mixed in a ratio of 9 : 1, was slightly acidic (pH 6.5), contained small amounts of nutrients and had very good air and water properties, which in the case of rooting bulbous plants is an advantageous feature (Wojdyła et al. 2022).

The bulbs were planted in a way that 2/3 of the bulb was above the surface of the substrate. All the pots with bulbs were subsequently placed in plastic boxes (crates) size 60 × 40 × 20 cm (length × width × height). The boxes were covered with an upholstery sponge measuring 60 × 40 × 2.5 cm and purposefully pressed with multiplates measuring 60 × 40 cm so that the bulbs could not be pushed out of the ground by the developing root system. The boxes were stocked on wooden pallets in the following way: five boxes on one level with 10–11 layers and transferred to cooling chambers adjusted precisely for 9 °C and 94–99% air humidity. After 4 weeks of the experiment, the pressure sponge covers were removed from the crates with the narcissus bulbs.

Measurements and observations. After the sprouted bulbs were taken out from the cold store (second stage), they were transferred to the greenhouse of the National Institute of Horticulture Research and placed on flooding tables in controlled conditions, where the temperature was kept at about 9 °C for several days (5–7 days) to undergo acclimatisation. After this period, the temperature in the greenhouse was increased to 16 °C and kept at this level until the end of cultivation. If necessary, the plants were watered in such a way that the surface of the substrate in the pot was slightly moist. In the greenhouse, during the full flowering period, the content of chlorophyll, flavonoids and the nitrogen balance index (NBI) were determined using the Dualex 4 meter (Force A, France). In full flowering, biometric measurements were performed, namely: total height, green mass height, the number of leaves per plant, leaf length, leaf width, the number of flowers per plant, the number of buds per plant, flower diameter, flower height, the length of individual petals, the width of individual petals the length of the corolla (trumpet), the width of the corolla (trumpet), the fresh weight of the plant without inflorescence, the dry weight of the plant without inflorescence, the fresh weight of flowers, and finally the dry weight of flowers.

A qualitative evaluation of plants was also carried out on a scale of 1–5 points, where: 1 – plants with slower growth, inflorescence poorly developed; 2 – plants with normal growth, inflorescence poorly developed; 3 – plants with proper growth, well-developed inflorescence; 4 – plants with uniform shape, well-developed inflorescence; 5 – very good shape and fully developed flowers. The root system of plants was also evaluated on a scale of 1–5 points, where: 1 – no visible roots; 2 – single roots visible in the root ball; 3 – good rooting, but the roots do not form a compact root ball; 4 – good rooting, roots form a compact root ball; 5 – very good rooting, very well-formed root ball.

Statistical analysis. The normality of the distribution of the 24 traits, i.e. initial height (IH), total height (TH), green part height (GPH), leaf number (LN), leaf length (LL), leaf width (LW), fresh mass of the above-ground part (without flowers) (FMA), dry weight of the above-ground part (without flowers) (DWA), days to flowering (DF), flower number (FN), flower buds number (FBN), fresh mass of flowers (FMF), dry mass of flowers (DDF), flower diameter (FD), flower height (from the base to the end of the cup) (FH), petal length (PL), petal width (PW), corolla appendage diameter (CAD), corolla appendage length (CAL), quality evaluation of plant (QEP), assessment of root system (ARS), chlorophyll Index DUALEX (CI), flavonoid Index DUALEX (FI), Nitrogen Balance Index (NBI), was verified with Shapiro-Wilk's normality. The homogeneity of variance was tested using Bartlett's test. Box's *M* test was used to check multivariate normality and homogeneity of variance-covariance matrices. All the traits had a normal distribution. A one-

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way (combinations) multivariate analysis of variance (MANOVA) was performed. A one-way analysis of variance (ANOVA) was performed to verify the null hypotheses of a lack of combination effect on the 24 observed traits, independently for each one. The arithmetic means, and standard deviations were calculated. Moreover, Fisher's least significant differences (LSDs) were estimated at a significance level of $\alpha = 0.05$. The relationships between observed traits were estimated using Pearson's linear correlation coefficients.

The results were also analysed using multivariate methods. A principal component analysis (PCA) was applied to present a multi-trait assessment of the similarity of the tested combinations in a lower number of dimensions with the least possible loss of information. The differences among the analysed combinations were verified by cluster analysis using the nearest neighbour method and Euclidean distances (Skomra et al. 2013). The GenStat version 18 statistical software package (VSN International) was used for the analyses.

RESULTS

The results of the MANOVA indicated that the effect of combinations (Wilk's $\lambda = 0.046$; $F = 6.53$; $P < 0.0001$) was significantly different regarding all the 24 quantitative traits. ANOVA indicated that the main effect of combinations was significant for all examined traits, except flower buds number, quality evaluation of plant, flavonoid Index DUALEX, and Nitrogen Balance Index (Table 1).

Table 1. Mean squares from one-way analysis of variance (ANOVA) for observed traits

Source of variation	Treatment	Residual
Trait (short key)	Degrees of freedom	
	8	711
Initial height in cm (IH)	2.75*	1.41
Total height in cm (TH)	15.0*	7.71
Green part height in cm (GPH)	9.61*	7.80
Leaf number (LN)	11.3*	10.3
Leaf length in cm (LL)	57.7***	6.10
Leaf width in cm (LW)	0.04*	0.02
Fresh mass of the above-ground part in g (without flowers) (FMA)	30.1**	11.3
Dry weight of the above-ground part in g (without flowers) (DWA)	0.53***	0.10
Days to flowering (DF)	5.68*	2.31
Flower number (FN)	5.93*	3.19
Flower buds number (FBN)	0.78	0.52
Fresh mass of flowers in g (FMF)	1.62***	0.31
Dry mass of flowers in g (DDF)	0.02**	0.01
Flower diameter in cm (FD)	1.90***	0.19
Flower height in cm (from the base to the end of the cup) (FH)	0.84***	0.09
Petal length in cm (PL)	0.84***	0.04
Petal width in cm (PW)	0.29***	0.03
Corolla appendage diameter in cm (CAD)	0.162***	0.04
Corolla appendage length in cm (CAL)	0.43***	0.03
Quality evaluation of plant in 1–5 scale (QEP)	0.32	0.36
Assessment of root system in 1–5 scale (ARS)	11.9***	0.66
Chlorophyll Index DUALEX (CI)	91.2*	42.5
Flavonoid Index DUALEX (FI)	0.04	0.02
Nitrogen Balance Index (NBI)	34.1	21.7

*,**,***significant levels at $P < 0.05$, 0.01, 0.001, respectively

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Table 2. Mean values, standard deviations (SD), Fisher's least significant differences (LSD) and homogeneous groups for combinations of traits

Trait	Comb	1	2	3	4	5	6	7	8	9	LSD
IH	mean	3.34^{abc}	2.94^{d}	3.50^{a}	3.04^{cd}	3.27$^{a–d}$	3.10^{bcd}	3.23$^{a–d}$	3.32^{abc}	3.44^{ab}	0.37
	SD	1.03	1.08	1.47	0.99	1.10	1.14	1.07	1.39	1.31	–
TH	mean	26.8^{ab}	27.0^{ab}	27.2^{a}	26.7^{ab}	26.4^{ab}	25.8^{c}	26.5^{abc}	26.6^{abc}	26.2^{bc}	0.86
	SD	2.51	3.09	2.87	2.79	2.80	2.67	3.01	2.42	2.77	–
GPH	mean	15.4^{ab}	14.6^{b}	15.0^{ab}	14.8^{ab}	14.7^{b}	15.7^{a}	14.8^{ab}	14.8^{ab}	14.7^{b}	0.87
	SD	2.443	2.67	2.72	2.68	2.49	4.05	2.72	2.43	2.57	–
LN	mean	11.6^{ab}	11.3^{ab}	11.5^{ab}	11.2^{ab}	10.7^{b}	10.9^{b}	11.4^{ab}	12.0^{a}	11.6^{ab}	1.00
	SD	3.53	3.31	3.54	2.84	2.75	2.95	3.23	3.63	3.02	–
LL	mean	16.5^{f}	16.8^{ef}	17.8^{cd}	17.6^{cde}	17.8^{cd}	17.1^{def}	18.2^{bc}	19.1^{a}	18.8^{ab}	0.77
	SD	2.36	2.49	2.32	2.28	2.32	2.33	2.53	2.66	2.87	–
LW	mean	1.11^{ab}	1.13^{a}	1.11^{ab}	1.08^{b}	1.14^{a}	1.11^{ab}	1.11^{ab}	1.08^{b}	1.10^{ab}	0.04
	SD	0.11	0.13	0.13	0.13	0.12	0.13	0.11	0.12	0.12	–
FMA	mean	16.5^{bc}	16.3^{c}	18.1^{a}	16.8^{bc}	17.0^{bc}	16.0^{c}	16.6^{bc}	17.4^{ab}	16.4^{bc}	1.04
	SD	3.45	2.99	3.68	3.19	3.51	3.20	3.309	3.35	3.47	–
DWA	mean	1.59^{de}	1.64^{bcd}	1.71^{abc}	1.57^{de}	1. 06de	1.52^{e}	1.63^{cd}	1.76^{a}	1.74^{ab}	0.10
	SD	0.30	0.28	0.32	0.29	0.31	0.30	0.33	0.34	0.36	–
DF	mean	14.61^{d}	14.7^{cd}	14.8^{bcd}	14.9^{bcd}	15.09^{abc}	15.2^{ab}	15.1^{abc}	15.1^{abc}	15.45^{a}	0.47
	SD	1.48	1.69	1.60	1.52	1.36	1.33	1.70	1.25	1.68	–
FN	mean	4.45^{abc}	4.51^{ab}	4.99^{a}	4.39^{bc}	4.04^{c}	4.50^{abc}	4.34^{bc}	4.49^{abc}	4.65^{ab}	0.55
	SD	1.83	1.55	1.81	1.57	1.47	1.86	1.83	1.89	2.16	–
FBN	mean	0.44^{a}	0.40^{a}	0.42^{a}	0.38^{a}	0.28^{a}	0.23^{a}	0.16^{a}	0.23^{a}	0.30^{a}	0.28
	SD	0.87	0.77	0.87	0.72	0.73	0.57	0.43	0.64	0.75	–
FMF	mean	1.99^{ab}	2.00^{a}	1.98^{ab}	1.88^{abc}	1.65^{de}	1.82^{bcd}	1.61^{e}	1.79^{cde}	1.79^{cd}	0.17
	SD	0.62	0.49	0.56	0.54	0.50	0.55	0.58	0.52	0.66	–
DDF	mean	0.28^{bc}	0.29^{ab}	0.31^{a}	0.28^{bc}	0.25^{c}	0.27^{bc}	0.26^{c}	0.27^{bc}	0.28^{bc}	0.03
	SD	0.09	0.08	0.08	0.08	0.08	0.10	0.08	0.07	0.10	–
FD	mean	4.54^{bc}	4.59^{b}	4.43^{cd}	4.83^{a}	4.64^{b}	4.59^{b}	4.45^{c}	4.42^{cd}	4.31^{d}	0.13
	SD	0.38	0.41	0.40	0.36	0.47	0.55	0.42	0.47	0.41	–
FH	mean	3.95^{b}	3.97^{b}	3.93^{b}	4.09^{a}	3.90^{b}	3.90^{b}	3.90^{b}	3.92^{b}	3.70^{c}	0.09
	SD	0.28	0.25	0.31	0.26	0.30	0.31	0.31	0.30	0.40	–
EN	mean	1.82^{cd}	1.87^{c}	1.80^{d}	2.04^{a}	1.95^{b}	1.95^{b}	1.79^{d}	1.80^{d}	1.71^{e}	0.07
	SD	0.14	0.19	0.18	0.39	0.21	0.24	0.13	0.15	0.15	–
PW	mean	1.15^{cd}	1.22^{ab}	1.12^{cde}	1.26^{a}	1.16^{c}	1.17^{bc}	1.10^{ef}	1.12^{def}	1.06^{f}	0.05
	SD	0.14	0.16	0.14	0.14	0.18	0.20	0.17	0.17	0.14	–
CAD	mean	1.72^{a}	1.68^{ab}	1.67^{abc}	1.60^{d}	1.61^{cd}	1.63^{bcd}	1.71^{a}	1.68^{ab}	1.62^{cd}	0.06
	SD	0.16	0.16	0.19	0.17	0.15	0.19	0.21	0.22	0.23	–
CAL	mean	1.66^{bc}	1.68^{b}	1.62^{cd}	1.74^{a}	1.64^{bc}	1.61^{cd}	1.57^{de}	1.54^{ef}	1.51^{f}	0.06
	SD	0.15	0.18	0.15	0.13	0.17	0.24	0.20	0.20	0.18	–
QEP	mean	4.36^{a}	4.38^{a}	4.39^{a}	4.35^{a}	4.35^{a}	4.37^{a}	4.39^{a}	4.41^{a}	4.19^{a}	0.29
	SD	0.61	0.57	0.59	0.55	0.63	0.60	0.61	0.59	0.61	–
ARS	mean	3.00^{a}	2.98^{a}	2.46^{bc}	3.06^{a}	2.59^{b}	2.15^{d}	2.24^{cd}	2.64^{b}	2.03^{d}	0.25
	SD	0.89	0.65	0.68	0.96	0.93	0.81	0.89	0.74	0.75	–
CI	mean	38.9^{a}	36.7^{b}	35.8^{b}	36.6^{b}	36.2^{b}	36.1^{b}	36.1^{b}	34.8^{b}	36.3^{b}	2.03
	SD	6.59	6.91	9.21	6.03	7.17	5.52	5.72	6.12	4.24	–
FI	mean	1.47^{a}	1.45^{a}	1.42^{a}	1.49^{a}	1.47^{a}	1.47^{a}	1.44^{a}	1.43^{a}	1.48^{a}	0.07
	SD	0.14	0.10	0.14	0.10	0.14	0.26	0.16	0.11	0.11	–
NBI	mean	26.6^{a}	25.4^{a}	25.1^{a}	24.6^{a}	24.6^{a}	25.1^{a}	25.3^{a}	24.5^{a}	24.65^{a}	2.17
	SD	4.82	4.74	5.94	3.86	4.60	4.780	4.87	4.64	3.14	–

1–9 – control (water), Bisteran 1%, Bisteran 2%, Bisteran 3%, Bisteran 5%, Bisteran 10%, Yamato 303 SE 0.5%, Signum 33 WG 0.5%, Biszop 80 WG 1%, respectively; LSD – the least significant difference (α = 0.05); for abbreviations of the traits, see Table 1; $^{a–f}$values in rows followed by the same letters are not significantly different

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Table 3. Correlation coefficients between 24 observed traits

Trait	IH	TH	GPH	LN	LL	LW	FMA	DWA	DF	FN	FBN	FMF	DDF	FD	FH	EN	PW	CAD	CAL	QEP	ARS	CI	FI
TH	0.09																						
GPH	0.02	–0.38																					
LN	0.44	0.39	–0.10																				
LL	0.47	–0.20	–0.50	0.42																			
LW	–0.10	0.00	–0.10	–0.58	–0.46																		
FMA	0.58	0.59	–0.30	0.31	0.40	–0.20																	
DWA	0.60	0.34	–0.50	0.78*	0.73*	–0.30	0.54																
DF	0.20	–0.80*	–0.10	–0.08	0.71*	–0.20	–0.20	0.21															
FN	0.41	0.37	0.15	0.52	0.07	–0.20	0.41	0.48	–0.14														
FBN	0.02	0.68*	0.00	0.09	–0.57	0.08	0.20	–0.03	–0.73*	0.40													
FMF	–0.10	0.59	0.23	0.28	–0.58	–0.10	0.08	0.01	–0.70*	0.60	0.87**												
DDF	0.13	0.67*	0.00	0.38	–0.22	–0.10	0.39	0.34	–0.49	0.87**	0.73*	0.85**											
FD	–0.71*	0.04	0.09	–0.65	–0.54	0.02	–0.20	–0.76*	–0.36	–0.49	0.26	0.12	–0.20										
FH	–0.55	0.48	0.09	–0.18	–0.48	–0.20	0.17	–0.46	–0.69*	–0.17	0.37	0.35	0.16	0.80**									
EN	–0.67*	–0.12	0.17	–0.74*	–0.44	0.03	–0.16	–0.76*	–0.19	–0.48	0.10	0.01	–0.20	0.96***	0.71*								
PW	–0.80*	0.22	0.06	–0.50	–0.65	0.04	–0.21	–0.66	–0.52	–0.28	0.43	0.39	0.12	0.94***	0.83**	0.87**							
CAD	0.16	0.44	0.12	0.59	–0.18	0.07	0.04	0.23	–0.51	0.18	0.06	0.21	0.14	–0.41	0.05	–0.55	–0.30						
CAL	–0.61	0.39	0.07	–0.49	–0.75*	0.15	–0.09	–0.67	–0.69*	–0.24	0.59	0.45	0.18	0.90***	0.85**	0.78*	0.94***	–0.20					
QEP	–0.29	0.39	0.19	–0.02	–0.25	0.03	0.31	–0.20	–0.55	–0.09	–0.09	0.06	0.02	0.29	0.67*	0.31	0.34	0.45	0.33				
ARS	–0.43	0.65	–0.10	0.03	–0.51	–0.10	0.09	–0.22	–0.79*	–0.20	0.65	0.54	0.24	0.64	0.81**	0.46	0.74*	0.16	0.80**	0.38			
CI	–0.07	0.17	0.33	–0.08	–0.74*	0.24	–0.42	–0.46	–0.54	–0.12	0.59	0.45	0.06	0.25	0.17	0.05	0.26	0.31	0.47	–0.20	0.45		
FI	–0.28	–0.49	0.10	–0.48	–0.23	–0.10	–0.57	–0.54	0.26	–0.46	0.12	–0.09	–0.40	0.50	–0.01	0.46	0.36	–0.60	0.33	–0.60	0.11	0.46	
NBI	0.02	0.28	0.47	0.14	–0.72*	0.31	–0.29	–0.31	–0.66	0.09	0.43	0.47	0.17	–0.04	0.14	–0.20	0.05	0.72*	0.26	0.19	0.30	0.83**	–0.10

For abbreviations of the traits, see Table 1

*,**,***significant levels at $P < 0.05$, 0.01, 0.001, respectively

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IH ranged from 2.94 cm (Bisteran 1%) to 3.50 cm (Biszop 80 WG); TH ranged from 25.8 cm (Bisteran 10%) to 27.2 cm (Bisteran 2%); GPH ranged from 14.6 cm (Bisteran 1%) to 15.7 cm (Bisteran 10%); an average of leaf number ranged from 10.7 pcs (Bisteran 5%) to 12.0 pcs (Signum 33 WG); leaf length ranged from 16.5 cm (control) to 19.1 cm (Signum 33 WG); leaf width ranged from 1.08 cm (Signum 33 WG) to 1.14 cm (Bisteran 5%); FMA ranged from 16.0 g (Bisteran 10%) to 18.1 g (Bisteran 2%); DWA ranged from 1.52 g (Bisteran 10%) to 1.76 g (Signum 33 WG). DF ranged from 14.6 days (control) to 15.5 days (Biszop 80 WG); average flower number ranged from 4.04 pcs (Bisteran 5%) to 5.00 pcs (Bisteran 2%); FBN ranged from 0.16 pcs (Yamato 303 SE) to 0.44 pcs (control); fresh mass of flowers ranged from 1.61 g (Yamato 303 SE) to 2.00 g (Bisteran 1%); dry mass of flowers ranged from 0.25 g (Bisteran 5%) to 0.31 g (Bisteran 2%); flower diameter ranged from 4.31 cm (Biszop 80 WG) to 4.81 cm (Bisteran 3%); flower height (from the base to the end of the cup) ranged from 3.70 cm (Biszop 80 WG) to 4.09 cm (Bisteran 3%); petal length ranged from 1.71 cm (Biszop 80 WG) to 2.04 cm (Bisteran 3%); petal width ranged from 1.06 cm (Biszop 80 WG) to 1.26 cm (Bisteran 3%); corolla appendage diameter ranged from 1.60 cm (Bisteran 3%) to 1.72 cm (control); corolla appendage length ranged from 1.51 cm (Biszop 80 WG) to 1.79 cm (Bisteran 3%).QEP ranged from 4.19 (Biszop 80 WG) to 4.41 (Signum 33 WG); ARS ranged from 2.03 (Biszop 80 WG) to 3.06 (Bisteran 3%); CI ranged from 34.8 (Signum 33 WG) to 38.9 (control); FI ranged from 1.42 (Bisteran 2%) to 1.49 (Bisteran 3%); NBI ranged from 24.5 (Signum 33 WG) to 26.6 (control) (Table 2).

The studies also revealed a significant correlation between observed traits. The positive correlations were observed between the following pairs of traits: TH-FBN (0.68), TH-DDF (0.67), LN-DWA (0.78), LL-DWA (0.73), LN-DF (0.71), FN-DDF (0.87), FBN-FMF (0.87), FBN-DDF (0.73), FMF-DDF (0.85), FD-FH (0.80), FD-PL (0.96), FD-PW (0.94), FD-CAL (0.90), FD-ARS (0.64), FH-PL (0.71), FH-PW (0.83), FH-CAL (0.85), FH-QEP (0.67), FH-ARS (0.81), PL-PW (0.87), PL-CAL (0.78), PW-CAL (0.94), PW-ARS (0.74), CAD-NBI (0.72), CAL-ARS (0.80), and CI-NBI (0.83). Negative correlations were observed between: IH-FD (–0.71), IH-PL (–0.67), IH-PW (–0.80), TH-DF (–0.80), LN-PL (–0.74), LL-CAL (–0.75), LL-CI (–0.74), LL-NBI (–0.72), DWA-FD (–0.76), DWA-PL (–0.76), DWA-PD (–0.66), DF-FBN (–0.73), DF-FMF (–0.70), DF-FH (–0.69), DF-CAL (–0.69), and DF-ARS (–0.79) (Table 3).

Figure 1 shows the variability of nine treatments on the basis of 24 traits in terms of the first two principal components. In the graph, the coordinates of the point for particular combinations are the values for the first and second principal components, respectively. The first two principal components accounted for 77.1% of the total multivariate variability between the individual combinations. Significant

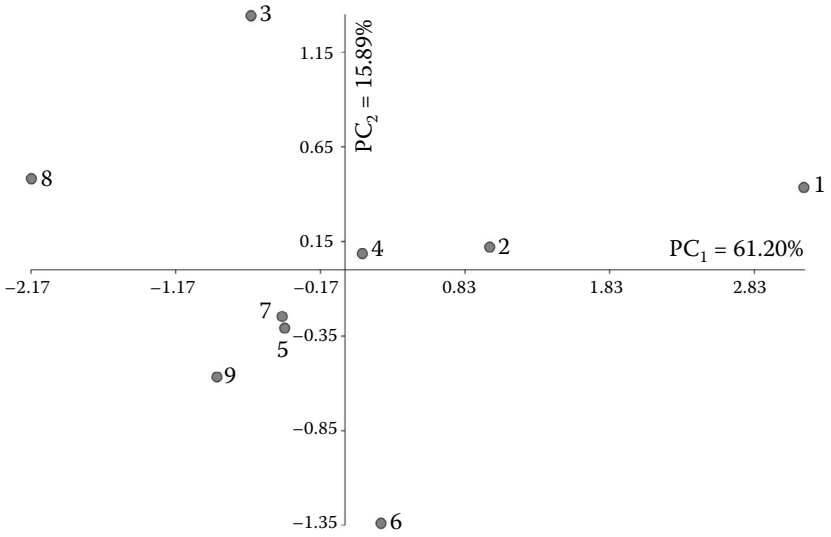

Figure 1. Distribution of combinations in space of two first principal components

1–9 – control (water), Bisteran 1%, Bisteran 2%, Bisteran 3%, Bisteran 5%, Bisteran 10%, Yamato 303 SE 0.5%, Signum 33 WG 0.5%, Biszop 80 WG 1%, respectively; $PC_{1,2}$ – principal components

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positive linear relationships with the first principal component were found for the CI and NBI, while the first principal component correlated negatively with LL. The second principal component had a significant positive correlation with TH and FMA (Table 4).

In the presented dendrogram, as a result of agglomeration grouping using the Euclidean method, all the examined combinations were divided into two groups. The first group included three treatments – Yamato 303 SE, Signum 33 WG and Biszop 80 WG. The second one included all the other combinations and was divided into two subgroups: A – control, Bisteran 1%, Bisteran 2%, and B – Bisteran 2%, 4% and 5% (Figure 2).

Table 4. Correlation coefficients between the first two principal components and studied traits

Trait	PC_1	PC_2
IH	–0.26	0.40
TH	0.19	0.93***
GPH	0.43	–0.29
LN	–0.18	0.52
LL	–0.90***	0.04
LW	0.34	–0.18
FMA	–0.46	0.81**
DWA	–0.59	0.50
DF	–0.66	–0.64
FN	–0.11	0.47
FBN	0.59	0.58
FMF	0.53	0.49
DDF	0.12	0.63
FD	0.36	–0.14
FH	0.31	0.36
EN	0.18	–0.25
PW	0.42	–0.02
CAD	0.35	0.42
CAL	0.59	0.17
QEP	0.03	0.36
ARS	0.50	0.48
CI	0.95***	0.03
FI	0.34	–0.57
NBI	0.88**	0.17

$PC_{1,2}$ – principal components; for abbreviations of the traits, see Table 1

,*significant levels at $P < 0.01$, 0.001, respectively

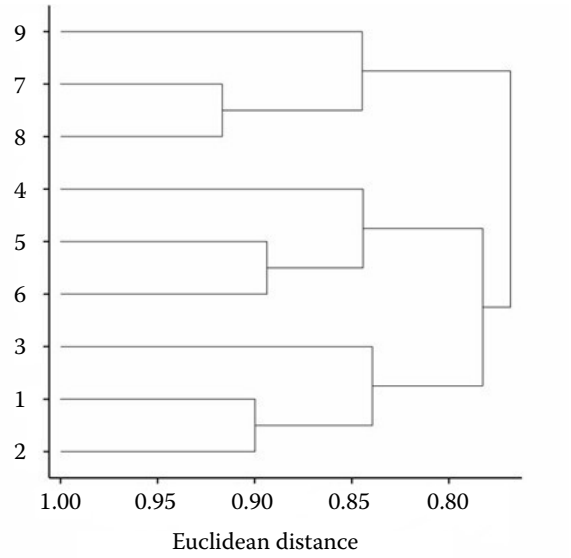

Figure 2. Dendrogram of cluster groupings of nine combinations based on all 19 quantitative traits
1–9 – control (water), Bisteran 1%, Bisteran 2%, Bisteran 3%, Bisteran 5%, Bisteran 10%, Yamato 303 SE 0.5%, Signum 33 WG 0.5%, Biszop 80 WG 1%, respectively

DISCUSSION

In our research, the stimulation of growth and development with the use of some H_2O_2-Ag^+ concentrations was observed with regard to plant height (TH), leaf length (LL), flower fresh weight (FMA), flower dry weight (DWA), number of days since exposure plants from cold storage for flowering (DF), the weight of fresh above-ground parts without flowers (FMF), the weight of dry above-ground parts without flowers (DDF), flower diameter (FD), flower height (FH), petal length (PL), petal width (PW) and the length of the crown process (CLA).

Similarly, earlier own research conducted on hyacinth also demonstrated a positive effect of H_2O_2-Ag^+ used for dressing bulbs on the stimulation of growth and development (Wojdyła et al. 2022). The positive effect of hydrogen peroxide with silver for treating narcissus bulbs on some of the studied traits, obtained in our studies, has also been confirmed in the research of other authors carried out on various species of crop plants.

In the studies carried out so far, the beneficial effect of hydrogen peroxide on plant growth and development and an increase in grain or fruit yield has been confirmed for maise (Ahmad et al. 2017), rice (Jira-anunkul, Pattanagul 2021), samarangi cap (*Syzygium samarangense*) (Khandaker et al. 2012),

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inducing the formation of adventitious roots and the growth of sweet potato seedlings (*Ipomea batatas*) (Deng et al. 2012), cucumber seedlings (*Cucumis sativus* L.) (Li et al. 2007).

A similar positive effect of silver nanoparticles (AgNPs) on the growth of watermelon and zucchini seedlings was shown in Almutairi and Alharbi (2015), as well as the growth of shoots and roots of rice seedlings (*Oryza sativa* L.) (Gupta et al. 2018).

The fungicides Signum 33 WG and Biszop 80 WG, used in our experiment to treat narcissus bulbs, stimulated leaf length (LL), fresh plant weight without flowers (FMF), and flower dry weight (DWA). However, these fungicides limited the length of petals (PL), the width of petals (PW), crown length (CAL), development of the root system (ARS) and chlorophyll index (FI), and delayed flowering (DF) compared to the control. Biszop 80 WG reduced flower diameter (FD), flower height (FH) and corolla diameter (CAD). Earlier research conducted on hyacinth also confirms the stimulation of hyacinth growth and development by the tested fungicides (Wojdyła et al. 2022).

In the literature, the data on the effect of fungicides on plant growth and development is categorised depending on the tested plant species. Previous studies have indicated that captan used to treat *Capsicum annuum* L. pepper seeds decreased the rate of seed germination (Tort, Turkyilmaz 2003) and plant growth (Seyhan et al. 2019). However, the negative impact of captan on bulb growth is not confirmed by research conducted by Manjunath and Bagyaraj (1984).

Most of the literature data evaluating the effect on plant growth and development concerns strobilurin fungicides. An increase and improvement in yield quality were found after treatment with strobilurin fungicides of wheat and barley (Venancio et al. 2003), maise (Ahmad et al. 2017), soybean (Swoboda, Pederson 2009), tomato (Mesara et al. 2021) and pepper (Joshi et al. 2014). In addition to stimulating plant growth, pyraclostrobin can enhance the plant defence system by inducing resistance (Li et al. 2020).

CONCLUSION

Stimulation of development and growth by means of the tested H_2O_2-Ag^+ concentrations was found in the case of plant height, leaf length, fresh flower weight, dry flower weight, number of days from leaving the cold store to flowering, the weight of fresh above-ground parts without flowers, the weight of dry above-ground parts without flowers, flower diameter, flower height, petal length, petal width and corolla length. The all tested fungicides stimulated leaf length, the weight of fresh plants without flowers, and Signum 33 WG and Yamoto 303 SE – the weight of dry flowers. It should be emphasised that none of the tested substances used to treat narcissus bulbs was phytotoxic (it did not cause damage to flowers and leaves). The obtained results may be useful for the practical use of hydrogen peroxide with silver as a completely safe agent for humans, animals, and the environment as a form of treatment for narcissus bulbs before rooting them in a cold store. Based on the results obtained, for practical use, it is recommended to season narcissus bulbs before planting in a 20-minute soak using Bisteran at a concentration of 2–3% or one of the tested fungicides: Biszop 80 WG, Signum 33 WG and Yamato 303 SE. Of the above-mentioned products, Bisteran (silver-stabilised hydrogen peroxide) deserves special attention due to its safety for humans, animals and the environment.

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