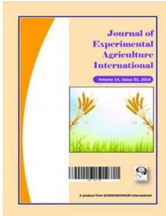


Journal of Experimental Agriculture International

19(4): 1-11, 2017; Article no.JEAI.38178
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

pH of Water and Tank Mixture Comprising Growth Regulator and Agrochemicals in Wheat

Deivid Luis Vieira Stefen[1], Clovis Arruda Souza[1*] and Cileide Maria Medeiros Coelho[1]

[1]Laboratory of Crop Plants, Agroveterinary Science Center, Department of Agronomy, Santa Catarina State University, Luiz de Camões Avenue 2090, Zip Code 88520-000, Lages, SC, Brazil.

Authors' contributions

This work was carried out in collaboration between all authors. The authors assisted in literature searches, writing in the manuscript and discussing the data. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2017/38178
Editor(s):
(1) Aleksander Lisowski, Professor, Department Agricultural and Forestry Engineering, Warsaw University of Life Sciences, Poland.
Reviewers:
(1) Ewuzie, Ugochukwu, Abia State University, Nigeria.
(2) Aliva Patnaik, Sambalpur University, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/22607

Original Research Article

Received 16th November 2017
Accepted 2nd December 2017
Published 5th January 2018

ABSTRACT

Aims: The aim of this study was to evaluate, under field conditions, the effect of lowering previously the of pH of the water used in the tank mixture spraying of trinexapac-ethyl, (imidacloprid + beta-cyfluthrin), (trifloxystrobin + tebuconazole) and iodosulfuron-methyl on plant height, agronomic traits and phytotoxicity caused to wheat plants.

Study Design: The study used a randomized block design with four replications. The treatments were distributed into a 2 x 13 factorial arrangement.

Place and Duration of Study: A field experiment was carried out during the 2016 growing season, from July, 22 to December, 5. The experiment was conducted at experimental farm of Santa Catarina State University, Lages, Santa Catarina state, Brazil.

Methods: The treatments consisted of the presence and absence of a pH reducer (phosphoric acid) and thirteen mixtures corresponding to different combinations of the trinexapac-ethyl growth regulator and iodosulfuron-methyl herbicide, (trifloxystrobin + tebuconazole) fungicide and the (imidacloprid + beta-cyfluthrin) insecticide.

Results: The use of low pH water did not increase phytotoxicity caused by the mixtures of

**Corresponding author: E-mail: souza_clovis@yahoo.com.br;*

trinexapac-ethyl, (imidacloprid + beta-cyfluthrin), (trifloxystrobin + tebuconazole) and iodosulfuron-methyl. There was no effect of the pH reducer and the mixtures on plant lodging, yield components and wheat grain yield.

Conclusion: The use of a spray solution at pH 4.0 enhances the effect of trinexapac-ethyl in decreasing plant height, but without changing the productive potential of wheat.

Keywords: Triticum aestivum; pesticides; acidity; spraying; tank mix.

1. INTRODUCTION

The mixture of agrochemicals in a spray tank is a common practice among farmers [1]. However, this may involve herbicides, fungicides, insecticides, foliar fertilizers and growth regulators, especially in cereals. The physicochemical properties of these substances are altered in aqueous medium and may influence the effectiveness of the tank mixture [2]. Water is used as diluent in all spray mixtures.

The pH of water is a factor that can influence the efficiency of spray application. When the pH is high, alkaline hydrolysis of the products may occur, given that the dissociation constant of ionic molecules depends on the pH. At low pH the hydrolysis rate is slow, maintaining the water film on the plant leaf for longer time [3].

Reducing the pH value of the spray solution is a promising technique in improving agrochemical absorption, reducing product doses and production costs and thereby maintaining efficient control. Inoue et al. [4] observed that a lower dose of glyphosate and the addition of a pH reducer to the spray solution enabled more efficient weed control compared to the same dose applied without the pH reducer. Applying gluphosinate with water at a pH of 4.0 resulted in lower weed density and biomass compared to water with a pH of 9.0 [5]. Applying the herbicide mesotrione with water at pH 6.5 exhibited the same weed control percentage as the solution prepared with water at a pH of 4.0, but was higher than the solution with a pH of 9.0 [6].

During agrochemical formulation, precautions are taken so that molecules can tolerate slight variations in pH, but extreme fluctuations may affect their stability [7]. To correct the spray solution, pH is generally lowered by adding a weak or diluted acid. Using pH reducers, primarily acids such as phosphoric acid, is a common practice in agrochemical applications aimed at raising the efficiency of the mixtures. In a mixture containing different classes of agrochemicals, pH reducers can heighten the effect of these combinations, whether by reducing incompatibility or chemically stabilizing the molecules, mainly for products that require a pH between 3 and 5, thereby avoiding their hydrolysis [8].

The aim of this study was to assess, under field conditions, the effect of lowering previously the pH of water used in spray tank mixtures of plant growth regulator (trinexapac-ethyl), inseticide (imidacloprid + beta-cyfluthrin), fungicide (trifloxystrobin + tebuconazole) and herbicide (iodosulfurom-methyl) on plant height, agronomic characteristics and phytotoxicity caused to wheat plants.

2. MATERIALS AND METHODS

2.1 Site Location and Sowing Date

The experiment was conducted in Lages, Santa Catarina state, Brazil from July 22 to December 5, 2016 with the wheat cultivar BRS Gralha Azul. The cultivar is of medium plant height, ranging from 80 to 100 cm, with an average number of tillers and moderate lodging tolerance [9].

Direct seeding was employed, using a plot seeder (Sêmina, Embrapa-Semeato), with soybean as the preceding crop. The plots were composed of 5 rows 5 m in length, spaced 0.2 m apart and 0.5 m between plots.

According to the results of soil analysis, basal dressing fertilizer was used with the application of 30 kg/ha of nitrogen, 80 kg/ha of P_2O_5 and 60 kg/ha of K_2O at seeding and 90 kg/ha of N as top dressing at the start of tillering. This fertilizer aimed at a potential yield of 4 tons of grains per hectare, based on the Soil Chemistry and Fertility Commission - RS/SC [10].

Weed, pest and disease control were carried out as needed, using the chemical products recommended for the crop. Chemical products were not applied 15 days before and 28 days after the treatments, to prevent interference in the results, primarily the degree of phytotoxicity.

2.2 Treatments and Experimental Design

The experimental design consisted of random blocks with four repetitions. Treatments were distributed into a 2 × 13 factorial design, with the presence and absence of a pH reducer and 13 mixtures corresponding to the different interactions between the plant growth regulator (100 g/ha of trinexapac-ethyl) and herbicide (5 g/ha of iodosulfurom-methyl), fungicide (75+150 g/ha of trifloxystrobin + tebuconazole) and insecticide (55+84 g/ha of imidacloprid + beta-cyfluthrin), as described in Table 1. All amounts of agrochemicals are on basis in active ingredient.

In the presence of the pH reducer, the pH of the water used to prepare the treatments was previously changed to 4.0 ± 0.1, with 1 mol/L phosphoric acid using of a pH meter. In the absence of the reducer, the pH of the water was not altered, maintaining the natural pH of 6.5. The water used in the experiment originated in the reverse osmosis purification process, in order to avoid other contaminants (chemicals) that could potentially interfere in the assessment. After preparation, the spray solutions were applied using a CO_2-pressurized backpack sprayer, with XR11002-VP Teejet spray nozzles, regulated to a flow rate of 200 L/ha. Treatments were applied on September 16 (58 days after sowing) when the plants were at the onset of stem elongation – first node visible, considering growth stage 31 (GS31) of Zadoks scale [11].

2.3 Evaluated Parameters

Wheat Plant Phytotoxicity: was assessed at 1, 7, 14, 21 and 28 days after application (DAA) of the mixtures based on scale scores, where 1 represents no symptoms and 9 plant death in line with the method proposed by the European Weed Research Council – EWRC [12].

Plant Height (HP): The mean plant height was assessed at pre-harvest, measured from the crown to the apex of the spike (less the awn) using a graduated ruler (mm). This assessment was conducted in 20 plants randomly collected from each plot. Plants in the central row of each experimental plot were also sampled to assess their morpho-agronomic characteristics.

Number of Grains per Spike (NGS): The 10 ears were collected from the central row of each plot, in which the NGS was handled quantified.

Number of Spikelets per Spike (NSS): The 10 ears were collected from the central row of each plot, in which the NSS was handled quantified.

Lodging Index (LI): The Belgian lodging index of the plants was assessed, using the equation LI = S × I × 2, where S = lodged surface between 1 and 10, where 1 is no lodging and 10 totally lodged and I – lodging intensity, ranging from 1 to 5, where 1= vertical plants, 5 = horizontal plants and 2 = correction coefficient [13,14].

Table 1. Description of the different mixture combinations between the growth regulator, herbicide, insecticide and fungicide, Lages – SC

Treatment	Number	Description
Control*	1	control, only water
GR	2	trinexapac-ethyl
GR+I	3	trinexapac-ethyl + (imidacloprid + beta-cyfluthrin)
GR+F	4	trinexapac-ethyl + (trifloxystrobin + tebuconazole)
GR+H	5	trinexapac-ethyl + iodosulfurom-methyl
GR+F+I	6	trinexapac-ethyl + (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin)
GR+H+I	7	trinexapac-ethyl + iodosulfurom-methyl + (imidacloprid + beta-cyfluthrin)
GR+H+F	8	trinexapac-ethyl + iodosulfurom-methyl + (trifloxystrobin + tebuconazole)
GR+F+I+H	9	trinexapac-ethyl + (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin) + iodosulfurom-methyl
H+F	10	iodosulfurom-methyl + (trifloxystrobin + tebuconazole)
H+I	11	iodosulfurom-methyl + (imidacloprid + beta-cyfluthrin)
F+I	12	(trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin)
F+I+H	13	(trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin) + iodosulfurom-methyl

**T, treatments; GR, growth regulator; I, insecticide; F, fungicide and H, herbicide*

Grain ripeness was identified on December 5, 2016 (Zadoks code GS92) and the crop was harvested in the useful area of each experimental unit, using a self-propelled plot harvester. After harvest, the following were determined in a sample of each plot:

Hectoliter Weight (HW): The weight of hectoliter was measured according to the Brazilian official wheat grain quality roles (Brazil, Ministry of Agriculture, Livestock and supply, Normative role 38, from November 30 of 2010), using a hectoliter weight analyzer (Dalle-Molle, model T40EL, 0.25L of capacity). Briefly, grain samples from each experimental plot were placed in the analyzer for volume determination and then weighed using a Dalle-Molle balance.

The percentage of grains larger than 1.75 mm (S>1.75): The S>1.75 was evaluated in a 100 g sample from each experimental plot using a 1.75 × 20 mm mesh sieve.

The 1000 Grain Weight (1000 GW): A sample of a thousand grains', obtained from each experimental plot were electronically counted (Sanick, model ESC 2011) and weighted using a precision balance 0.01 g and expressed in grams (g).

Grain Yield (GY): was calculated based on the weight of grains obtained in the useful study area of the plots, corrected for 13% moisture (wet basis) and converting the value for one hectare.

The HP, NGS, NSS, LI, HW, 1000 GW and GY were evaluated in a similar manner as a described for oat according to Uarrota et al. [14].

2.4 Statistical Analysis

The data obtained were in subjected to analysis of variance using the F-test ($p \leq 0.05$). Data were checked for normality distribution (Shapiro-Wilk W test) and homogeneity of variance (Levene's test). When statistical significance was reached, the means of the mixtures were compared by applying the Scott-Knott test at 5% probability and the means of the pH reducer by Tukey's test at 5% probability. The evolution of phytotoxicity over time was determined by regression analysis. Hierarchical cluster was carried out using Ward's method, applying Euclidean distance as dissimilarity measure. Treatments were grouped according to plant phytotoxicity. Statistical analysis was performed using R software version 3.4.2 / R-project website [15].

3. RESULTS AND DISCUSSION

Analysis of variance showed effect of pH reducer, mixtures and interaction of pH reducer with mixtures ($p<0.05$) on HP (Table 2). For NSS, there was an effect only for the pH reducer, and for HW only a single effect of mixtures (Table 2).

Applying trinexapac-ethyl alone or in a mixture with other agrochemicals, in the presence or not of the pH reducer, decreased plant height, in contrast to treatments without the growth regulator (Table 3). Without the pH reducer, the mixtures that contained trinexapac-ethyl resulted in smaller plants, differing from the control and plants treated with mixtures without the growth regulator. A similar result occurred when the mixtures were applied with a pH reducer.

Table 2. Analysis of variance, mean square, residual, mean and coefficient of variation with respect to the application of tank mixtures among plant growth regulator, herbicide, insecticide and fungicide with and without the pH reducer on wheat plant traits. Lages – SC, 2016 growing season

	Mean square						
Source of variation	**HP (cm)**	**GY (kg/ha)**	**HW (kg/100 L)**	**1000 GW (g)**	**NSS (nº)**	**NGS (nº)**	**S>1.75 (%)**
pH reducer (A)	129.4*	50349^{ns}	1.0^{ns}	1.0^{ns}	10.7*	0.2^{ns}	0.48^{ns}
Mixtures (B)	235.9*	623789^{ns}	2.4*	7.0^{ns}	3.1^{ns}	27.7^{ns}	0.13^{ns}
A×B	64.1*	335005^{ns}	0.5^{ns}	9.4^{ns}	3.4^{ns}	10.6^{ns}	0.19^{ns}
Block	48.0^{ns}	294715^{ns}	2.9^{ns}	0.6^{ns}	2.8^{ns}	6.3^{ns}	0.06^{ns}
Residual	19.8	823768	0.9	5.5	1.9	23.0	0.3
Mean	81.1	3880.6	77.3	37.3	16.9	30.5	99.0
CV (%)	5.5	23.4	1.2	6.3	8.2	15.7	0.5

HP = Plant Height, GY = Grain Yield, HW = Hectoliter Weight, 1000 GW = 1000 Grain Weight, NSS = Number of Spikelets per Spike, NGS = Number of Grains per Spike, S>1.75 = Percentage of grains larger than 1.75 mm, '^{ns}' not significant ($p>0.05$) and '' significant ($p \leq 0.05$)*

However, GR+H+F and GR+H+I+F treatments produced shorter plants, and GR, GR+I, GR+F, GR+H, GR+F+I and GR+H+I mixtures exhibited intermediate values, but with lower plant height than that obtained without the plant growth regulator (Table 3).

Table 3. Single effects and interactions for height of wheat plants as a function of tank mixture of trinexapac-ethyl (GR) and iodosulfurom-methyl (H), trifloxystrobin + tebuconazole (F) and imidacloprid + beta-cyfluthrin (I) with (WR) and without the pH reducer (WoR), Lages – SC. 2016 growing season

Treatments	Plant Height (cm)	
	Without pH reducer (WoR)	With pH reducer (WR)
Control	85.5 aA	85.3 bA
GR	81.5 bA	73.5 dB
GR+I	81.0 bA	71.0 dB
GR+F	81.8 bA	73.0 dB
GR+H	78.3 bA	74.0 dA
GR+F+I	79.3 bA	75.0 dA
GR+H+I	80.3 bA	71.8 dB
GR+H+F	78.0 bA	78.0 cA
GR+F+I+H	76.3 bA	80.8 cA
H+F	84.3 aB	91.3 aA
H+I	87.5 aA	89.3 aA
F+I	87.5 aA	92.0 aA
F+I+H	87.8 aA	85.0 bA
Mean	82.2	80.0

Means followed by the same lowercase letters in the column and uppercase on the row did not differ according to the Scott-Knott test at 5% probability

When the pH of the spray solution declined to 4.0, GR, GR+I, GR+F and GR+H+I treatments resulted in shorter plants, compared to those applied without reducing solution pH. Trinexapac-ethyl is an acidic product with a pKa value of 4.6 [16]. Weak acidic products and lowering the pH improves efficiency, given that less ionized molecules penetrate the cuticle and the plasma membrane more easily [17]. According to Green & Cahill [18], the syrup pH interferes in molecular activity. Reducing the pH facilitates cuticular penetration and solubility, thereby improving molecular absorption and allowing for lower doses of the products [4]. When assessing the effect of trinexapac-ethyl on the height of wheat plants, Zagonel & Fernandes [19] and Stefen et al. [20] investigated the response to trinexapac-ethyl by decreasing height as a function of applying this regulator. This may explain why GR, GR+I, GR+F and GR+H+I treatments resulted in shorter plants when applied with pH 4.0 water, likely due to the greater absorption of the product. However, GR+H, GR+F+I, GR+H+F and GR+F+I+H did not differ when applied with and without the pH reducer. This may have occurred because of the interaction with other products.

The effect of reducing plant height on decreasing lodging was not observed, since the climatic conditions did not favor lodging. Particularly, the mean HP values of 82.2 cm (WoR) and 80.0 cm (WR) was below of observed for this cultivar, BRS Gralha Azul, that is 83 cm at previous research [9].

Mixtures of trinexapac-ethyl, iodosulfurom-methyl, (trifloxystrobin + tebuconazole) and (imidacloprid + beta-cyfluthrin) produced a significant effect on HW, with the best results obtained in treatments GR+I, GR+F, GR+H, GR+F+I, GR+H+I, GR+H+F, H+I and F+I (Table 4). The HW indirectly expresses grain quality, and is more associated with the genetic characteristics of the genotype and strongly related to gluten strength and industrial flour quality [21]. Crop problems due biotic and abiotic factors that affect grain filling in wheat may decease HW values [22].

Table 4. Hectoliter weight (HW) as a function of tank mixture of trinexapac-ethyl (GR) and iodosulfurom-methyl (H), trifloxystrobin + tebuconazole (F) and imidaclopride + beta-cyfluthrin (I) in the wheat crop, Lages – SC. 2016 growing season

Treatments	HW (kg/100 L)
Control	76.3 b
GR	76.8 b
GR+I	77.4 a
GR+F	77.9 a
GR+H	78.2 a
GR+F+I	77.9 a
GR+H+I	77.5 a
GR+H+F	77.3 a
GR+F+I+H	76.8 b
H+F	77.0 b
H+I	77.5 a
F+I	77.6 a
F+I+H	76.8 b
Mean	**77.3**

Means followed by the same letters do not differ according to the Scott-Knott test at 5% probability

The number of spikelets per spike (NSS) was affected by the pH reducer (Table 5). WoR to prepare the spray solution, the mean NSS (17.3) was higher than the NSS, exhibiting WR (16.6).

Despite this difference in NSS, there was no change in NGS or 1000GW.

Table 5. Number of spikelets per spike (NSS), as a function of the tank mixture of trinexapac-ethyl (GR) and iodosulfurom-methyl (H), trifloxystrobin + tebuconazole (F) and imidacloprid + beta-cyfluthrin (I) with and without the pH reducer in the wheat crop, Lages – SC. 2016 growing season

Treatments	Number of spikelets per spike (NSS)
Without pH reducer (WoR)	17.3 a
With pH reducer (WR)	16.6 b

Means followed by the different lowercase letters do differ according to Tukey's test at 5% probability

According to Gondim et al. [23], the number of grains per spike and 1000 grains weight had a positive effect on grain yield. Since the application of mixtures WR or WoR had no effect, no significant change in grain yield was observed.

No phytotoxicity symptoms were detected at 1, 7, 14, 21 and 28 DAA in the treatments, control and treatment containing only trinexapac-ethyl (GR), with a score of 1 on the EWRC scale. The other treatments resulted in phytotoxicity scores ranged from 2 to 5; with the first phytotoxicity symptoms observed after 7 DAA. At 7, 14, 21 and 28 DAA there was a linear increase in phytotoxicity in GR+H+I, F+I, and F+I+H (Fig. 2A, 3B and 3C) and a quadratic response was detected in GR+I, GR+F, GR+F+I, GR+H+F, GR+F+I+H and H+F (Figs. 1A, 1B, 1D, 2B, 2C and 2D).

The GR+I (WoR) and H+I (WR) treatments (Figs. 1C and 3A) showed a linear response when the

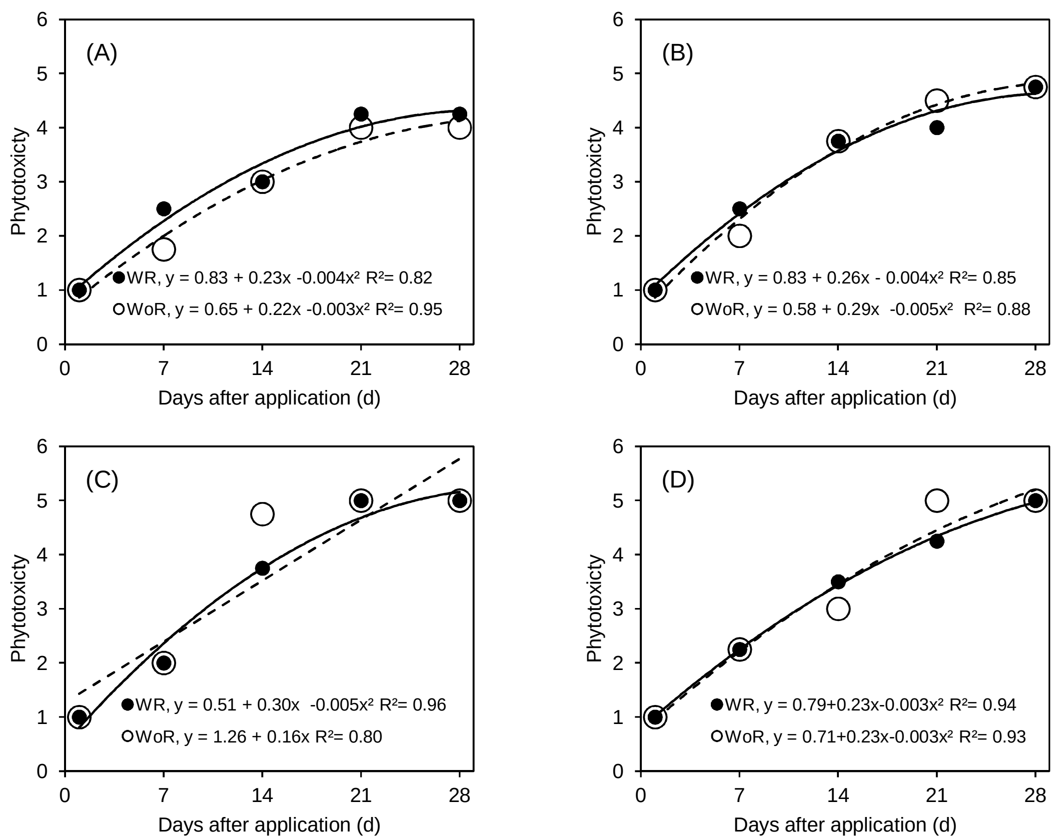


Fig. 1. Phytotoxicity in wheat plants caused by foliar application of tank mixtures with (WR) and without the pH reducer (WoR). 2016 harvest. (A) trinexapac-ethyl + (imidacloprid + beta-cyfluthrin), (B) trinexapac-ethyl + (trifloxystrobin + tebuconazole), (C) trinexapac-ethyl + iodosulfurom methyl, (D) trinexapac-ethyl + (trifloxystrobin+tebuconazole) + (imidacloprid + beta-cyfluthrin)

pH of the water was reduced to 4.0, and without the pH reducer the response was quadratic. Both treatments were attributed only a max score of 5 on the scale.

Reducing the pH of water to 4.0 in the mixtures had no effect on phytotoxicity. The maximum score obtained for phytotoxicity was 5 on the EWRC scale, for treatments WoR and WR for a

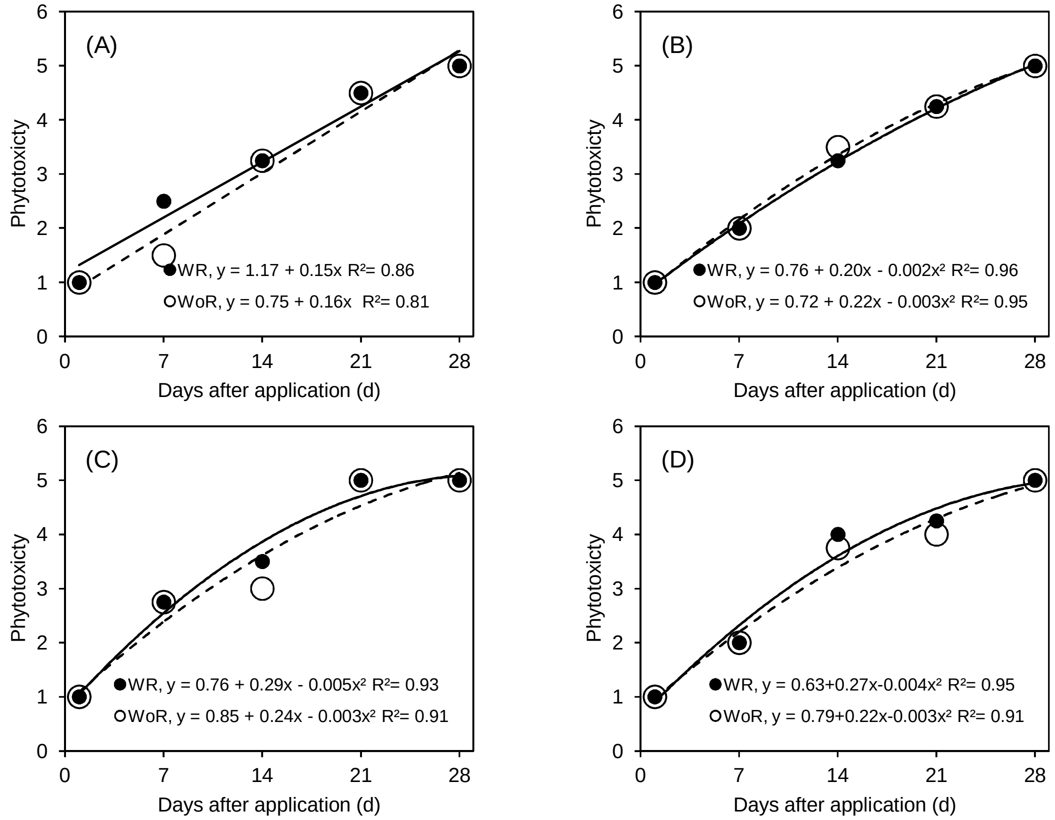
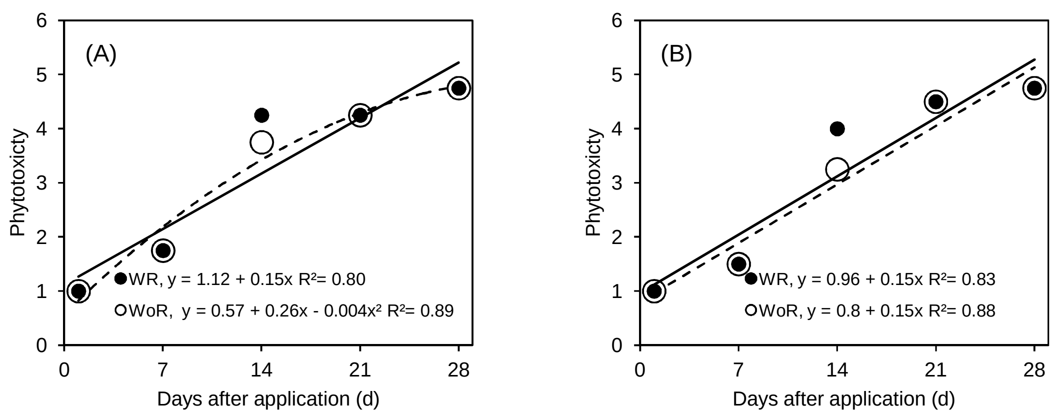


Fig. 2. Phytotoxicity in wheat plants caused by the foliar application of tank mixtures with and without the pH reducer. 2016 growing season. (A) trinexapac-ethyl, iodosulfurom methyl + (imidacloprid + beta-cyfluthrin), (B) trinexapac-ethyl, iodosulfurom methyl + (trifloxystrobin+tebuconazole), (C) trinexapac-ethyl + (trifloxystrobin + tebuconazole) + (imidacloprid + betacyfluthrin) + iodosulfurom methyl and (D) iodosulfurom methyl + (trifloxystrobin+tebuconazole)



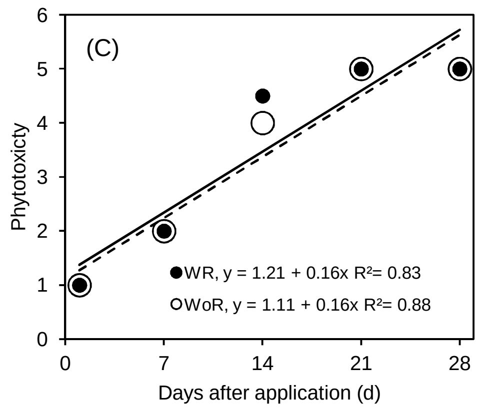


Fig. 3. Phytotoxicity in wheat plants caused by the foliar application of tank mixtures with and without the pH reducer: (A) iodosulfurom methyl + (imidacloprid + beta-cyifluthrin), (B) (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin) and (C) (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin) + iodosulfurom methyl

reduction of pH to 4.0. Decreasing the pH of the spray solution interferes in the ease of cuticular penetration, improving agrochemical absorption [17]. The hydrolysis rate is slower at a lower pH, which keeps the leaf wet for longer due to the neutral pH of its surface and with the spray solution pH. It was expected that lower water pH would lead to higher plant phytotoxicity, owing to greater product absorption; however, this was not observed in our experiment. According to Whitford et al. [24], herbicides, fungicides and insecticides function better when the water used has a pH between 4.0 and 6.5. Since the pH range used in the experiment was between 4.0 and 6.5, there was no difference in phytotoxicity between the plants treated with mixtures of trinexapac-ethyl, (trifloxystrobin + tebuconazole), iodosulfurom-methyl and (imidacloprid + beta-cyfluthrin) at pH 4.0 or 6.5.

Hierarchical clustering was applied to the phytotoxicity data, in order to group treatments according to their impact on wheat plants. Cluster analysis separated the 26 treatments (2 × 13; with and without a spray solution pH reducer combined with the 13 mixtures of products) into 4 groups (Fig. 4).

The first group consisted of the control and trinexapac-ethyl with and without the pH reducer. These treatments did not cause phytotoxicity in wheat plants. The second group was composed of trinexapac-ethyl + (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin) + iodosulfurom-methyl and trinexapac-ethyl + (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin) applied with and without the pH reducer and trinexapac-ethyl + imidacloprid + beta-cyfluthrin, trinexapac-ethyl + (trifloxystrobin + tebuconazole), trinexapac-ethyl + iodosulfurom-methyl + (imidacloprid + beta-cyfluthrin) with the syrup pH reducer. The third group contained (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin), iodosulfurom-methyl + (imidacloprid + beta-cyfluthrin) with and without the pH reducer, trinexapac-ethyl + (imidacloprid + beta-cyfluthrin) and trinexapac-ethyl + iodosulfurom-methyl + (imidacloprid + beta-cyfluthrin) without the pH reducer. The fourth group consisted of (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin) + iodosulfurom-methyl, trinexapac-ethyl + iodosulfurom-methyl, trinexapac-ethyl + iodosulfurom-methyl + (trifloxystrobin + tebuconazole), iodosulfurom-methyl + (trifloxystrobin + tebuconazole) with and without the pH reducer and trinexapac-ethyl + (trifloxystrobin + tebuconazole) without the pH reducer.

The clustering of mixtures with and without the pH reducer indicates similar traits in terms of the degree of phytotoxicity caused to wheat plants. The cophenetic correlation obtained was 98%. The use of cophenetic correlation for measure the degree of fit between the dissimilarity matrix and the resulting matrix of simplification due to the clustering method. The value close to 100% indicates that the grouping method used was adequate. The grouping the most similar treatments for the degree of phytotoxification was successfully obtained, pointing that cophenetic correlation was appropriate for this purpose.

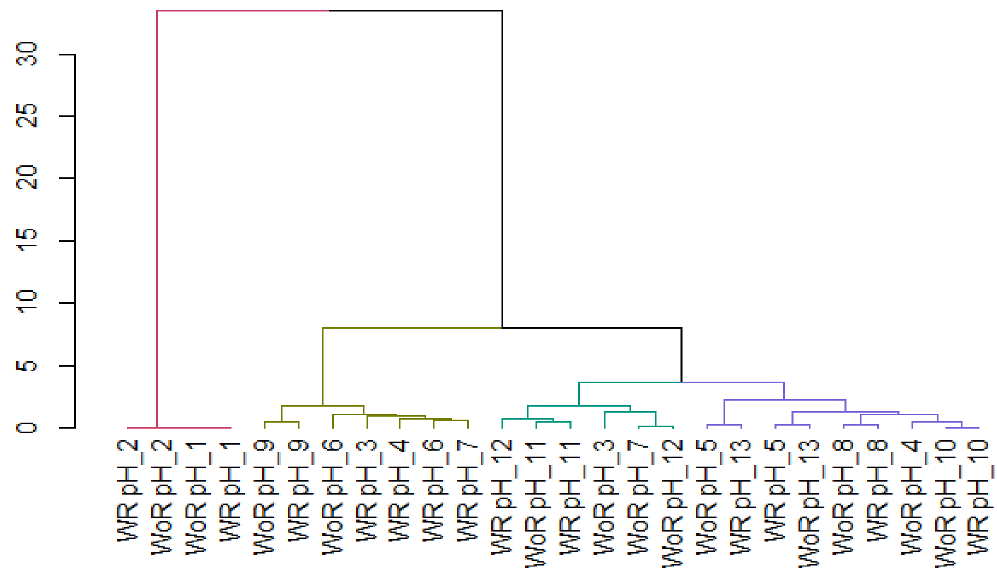


Fig. 4. Hierarchical dendrogram of the thirteen mixtures with and without a spray solution pH reducer showing the similarities and dissimilarities between treatments in terms of the degree of phytotoxicity caused to plants. WoR pH: without a pH reducer; WR pH: with a pH reducer combined to products: (GR) trinexapac-ethyl, (I) imidacloprid + beta-cyfluthrin, (F) trifloxystrobin + tebuconazole and (H) iodosulfurom-methyl; Treatments: 1 Control, 2 GR, 3GR+I, 4GR+F, 5 GR+H, 6 GR+F+I, 7 GR+H+I, 8 GR+H+F, 9 GR+F+I+H, 10 H+F, 11 H+I, 12 F+I and 13 F+I+H

Most of the independent treatments applied WR or WoR were placed in the same group. However, the application of trinexapac-ethyl + (imidacloprid + beta-cyfluthrin), trinexapac-ethyl + (trifloxystrobin + tebuconazole) and trinexapac-ethyl + iodosulfurom-methyl + (imidacloprid + beta-cyfluthrin) with a spray solution pH reducer caused similar phytotoxicity to that provoked by trinexapac-ethyl + (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin) + iodosulfurom-methyl and trinexapac-ethyl + (trifloxystrobin + tebuconazole) + (imidacloprid + beta-cyfluthrin), that is, wheat plant phytotoxicity was similar to that caused by treatments with a larger number of products in the mixture. Thus, the number of agrochemicals mixed in the spray tank is not a determining factor in strengthening the phytotoxic effect on wheat plants. In general, these results are similar to those obtained by Gazzieiro [1].

4. CONCLUSION

The use of mixtures and water with a pH of 4 had no effect on wheat yield. The mixtures of trinexapac-ethyl, iodosulfurom-methyl, (imidacloprid + betacyfluthrin) and (trifloxytrobin + tebuconazole) led to moderate phytotoxicity in wheat plants. However, lowering the pH of water used in the spray solution did not influence the degree of phytotoxicity. Using spray solution with a pH of 4.0 increases the effect of trinexapac-ethyl on reducing plant height.

ACKNOWLEDGEMENTS

Technical assistance of students of Laboratory of Crop Plants, Department of Agronomy, Santa Catarina State University is to be acknowledged. Also thank CAPES-Brazil/CNPq-Brazil for providing fellowships and the programs PROAP/CAPES, PROMOP/UDESC and PAP/FAPESC/UDESC for financial assistance. The 2nd and 3th thanks CNPq for Research Productivity Fellowships.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gazziero DLP. Mixtures of pesticides in tank, in Brazilian farms. Planta Daninha. 2015;33(1):83-92. Portuguese

2. Azevedo LAS. Misturas de tanque de produtos fitossanitários: Teoria e prática. Rio de Janeiro: IMOS; 2015. Portuguese
3. Prado EP, Araújo D, Raetano CG, Dal Pogetto MHFA, Aguiar-Júnior HO, Christovam RS. Effects of water hardness and pH in acaricide spray solutions on the control of *Brevipalpus phoenicis* on sweet orange fruit. Bragantia. 2011;70(2):389-96. Portuguese
4. Inoue MH, Komatsu RA, Guerreiro RM, Dallacort R, Santana DC, Santana CC. Addition of pH reducers and rates of glyphosate in the weeds desiccation. Revista Brasileira de Herbicidas. 2007;6(1):22-31. Portuguese
5. Devkota P, Johnson WG. Glufosinate efficacy as influenced by carrier water pH, hardness, foliar fertilizer, and ammonium sulfate. Weed Technology. 2016;30(4): 848–59.
6. Devkota P, Spaunhorst DJ, Johnson WG. Influence of carrier water pH, hardness, foliar fertilizer, and ammonium sulfate on mesotrione efficacy. Weed Technology. 2016;30(6):617-28.
7. Inoue MH, Komatsu RA, Tanahashi RF, Possamai AS, Dallacort R, Piza MA. pH reducers and metals complexes in the laboratory. Revista Brasileira de Herbicidas. 2008;7(2):26-35. Portuguese
8. Petter FA, Segate D, Almeida FA, Neto FA, Pacheco LP. Physical incompatibility of mixing of insecticides and fungicides. Comunicata Scientiae. 2013;4(2):129-38. Portuguese
9. Bassoi MC. BRS-Gralha Azul cultivar de trigo. Passo Fundo: Empresa Brasileira de Pesquisa Agropecuária, Folder. 2012;1-2. Portuguese.
(Accessed 14 November 2017)
Available:http://pt.wikipedia.org/wiki/Gralha-Azul
10. Comissão De Química E Fertilidade Do Solo - RS/SC (CQFS-RS/SC). Manual de adubação e de calagem para os estados do Rio Grande do Sul e Santa Catarina. Porto Alegre: Sociedade Brasileira de Ciência do Solo – Núcleo Regional Sul; 2004. Portuguese
11. Zadoks JC, Chang TT, Konzak CF. A decimal code for the growth stages of cereals. Weed Research. 1974;14(1):415-21.
12. Robinson MA, Cowbrough MJ, Sikkema PH, Tardif FJ. Winter wheat (*Triticum aestivum* L.) tolerance to mixtures of herbicides and fungicides applied at different timings. Canadian Journal of Plant Science. 2013;93(3):491-501.
13. Moes J, Stobbe EH. Barley treated with ethephon: I yield components and net grain yield. Agronomy Journal. 1991;83(1): 86-90.
14. Uarrota VG, Souza CA, Sponchiado JC, Coelho CMM. Assessment of yield attributes and industrial quality parameters of oat cultivars (*Avena sativa* L.) using multivariate techniques (PCA, PLS-DA and OLS-R). Journal of Experimental Agriculture International. 2017;17(4):1-13.
15. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria; 2017.
Available:https://www.R-project.org/
16. Kiljanek T, Niewiadowska A, Semeniuk S, Gaweł M, Borzecka M, Posyniak. Multi-residue method for the determination of pesticides and pesticide metabolites in honeybees by liquid and gas chromatography coupled with tandem mass spectrometry – Honeybee poisoning incidentes. Journal of Chromatography A. 2016;1435:100-14.
17. Carvalho SJP, Damin V, Dias ACR, Yamasaki GM, Christoffoleti PJ. Efficacy and pH of glyphosate spray solutions after the addition of nitrogen fertilizers and the use of CO_2-pressurized sprayer. Pesquisa Agropecuária Brasileira. 2009;44(6):569-75. Portuguese
18. Green JM, Cahill WR. Enhancing the biological activity of nicosulfuron with pH adjusters. Weed Technology. 2003;17(2): 338-45.
19. Zagonel J, Fernandes EC. Rates and application times of growth reducer affecting wheat cultivars at two nitrogen rates. Planta Daninha. 2007;25(2):331-39. Portuguese
20. Stefen DLV, Souza CA, Coelho CMM, Tormen ME, Zanesco PR, Casa RT, Sangoi L, Nunes FR. Nitrogen management associated with growth retardants in wheat cv. Mirante. Revista de Ciências Agroveterinárias. 2014;13(1):30-39. Portuguese
21. Stefen DLV, Souza CA, Coelho CMM, Gutkoski LC, Sangoi L. Nitrogen topdressing during heading improve the industrial quality of wheat (*Triticum aestivum* cv. Mirante) grown with plant growth regulator etyl-trinexapac. Revista

de la Facultad de Agronomía. 2015;114(2):161-69. Portuguese
22. Franceschi L, Benin G, Guarienti E, Marchioro VS, Martin TN. Pre-harvest factors that affect wheat technological quality. Ciência Rural. 2009;39(5):1624-31. Portuguese
23. Gondim TCO, Rocha VS, Sediyama CS, Miranda GV. Path analysis for yield components and agronomic traits of wheat under defoliation. Pesquisa Agropecuária Brasileira. 2008;43(4):487-93. Portuguese
24. Whitford F. The impact of water quality on pesticide performance; 2017. (Accessed 14 June 2017) Available:https://www.extension.purdue.edu/extmedia/ppp/ppp-86.pdf

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/22607