A scale of grades for evaluation of herbicide weed control efficiency

Gustavo Rabelo Botrel Miranda[1], Marcelo Bregagnoli[2], Raphael Antônio Prado Dias[3]

[1] Federal Institute of Education, Science and Technology of South of Minas Gerais - IFSULDEMINAS, Campus Muzambinho. Research Professor Doctor. gustavo.miranda@muz.ifsuldeminas.edu.br.

[2] IFSULDEMINAS. Research Professor Doctor. marcelo.bregagnoli@muz.ifsuldeminas.edu.br.

[3] IFSULDEMINAS. Research Professor Doctor. raphael.dias@muz.ifsuldeminas.edu.br.

Abstract

The present work aims to describe a proposal of scale of grades for analysis of herbicide efficiency to make results of researches closer to the technical reality. The proposed scale of grades is based on a 5-percentage point scale (5-PPS), i.e., the weed control grade 1 is 0% to 4%, grade 2 is 5% to 9%, and so on up to 20 (95% to 99%) and 21 (100% weed control). This scale was based on three factors. The first considers the decreases in the coefficient of variation and standard deviation in statistical analyses, which improve the precision of results, when compared to a 20-percentage point scale (20-PPS), and the detection of significant differences between means that are not detected in the 20-PPS. The second factor is based on the comparison of the described symptomatologic analysis that attributes 5 grades that are, analogically, a 20-PPS. The proposed scale improves the statistical and agronomical evaluations. Therefore, the proposed methodology is better in differentiating results of weed control efficiency in field evaluations. The third factor considers improvements in the interpretation of results of herbicide efficiency, enabling the use of higher grades in the scale for studies on resistance to herbicides by indicating the selection pressure. It is concluded that the use of the proposed grading scale reduces the coefficient of variation and results in a better interpretation of the technical reality of the effects of herbicides.

Keywords: Chemical control. Evaluation method. Methodology. Statistics.

Introduction

The use of herbicides for weed control is an essential practice in many agricultural activities. Despite the many other weed control methods, such as cultural and mechanical (HIRATA; DUARTE; DUARTE, 2018), herbicides are used due to their easy management and longer weed killing effects (SILVA et al., 2018), resulting in longer times without weed competition with plants of interest (SILVA JR et al., 2018).

Weed control using herbicides can be evaluated directly or indirectly. Direct or quantitative evaluations are based on analysis of height, dry or fresh weight accumulation, density, and crop yield (SHAH et al., 2018). Indirect or qualitative evaluations are exclusively made by a scale of grades of toxicity or selectivity levels, classified by symptomatologic effects of herbicides on weeds and crops (LIMA et al., 2018; LUZ; FONSECA; DUARTE, 2018).

These grades can be described in 5 levels in a 20-percentage point scale (20-PPS).

The evaluation of percentages without scale of grades (1-PPS) used by Maciel et al. (2011), López-Ovejero et al. (2006); and Norris; Shaw; Snipes (2001) is an indirect evaluation of weed chemical control that increases the coefficient of variation of statistical analyses, and often require data transformation into arcsen of square root of x+1 (arcsen (x+1)0.5). Three people should evaluate the herbicide efficiency results in the field in indirect evaluations; thus, the results become more precise, improving statistical precision, and decreasing the coefficient of variation, standard deviation, and experimental data variance (CONAGIN; NAGAI; AMBROSIO, 2009).

Several technical manuals show results of herbicide efficiency using weed control percentages in 5-percentage point scale (5-PPS) (LORENZI, 2000). These values are closer to

those of technical interpretation and facilitate visual discrimination by technicians who use this information for agronomic recommendations. Moreover, the results of this proposed scale can assist the presentation of results grouped as susceptible, moderate, and tolerant (BAERSON *et al.*, 2002).

The probability of error in the accuracy of the grade attributed increases when changing it from a 20-PPS to a 5-percentage point scale (5-PPS), since grade 1, for example, is broader in 20-PPS, encompassing a higher number of grades, decreasing the possibility of errors. However, the 20-PPS scale is divided into 4 grades in this proposal (5-PPS); thus, the means attributed by the evaluators are more accurate and provide the possibility of studying other factors, such as selection pressure and weed control levels of herbicides.

In this proposed scale of grades, the grade representing 100%, and those representing 95% to 99% weed control can be used in studies of resistance to herbicides, since they easily identify the selection pressure as very high and high pressure, respectively.

According to Christoffoleti and Nicolai (2016) and Vargas and Roman (2006), weed resistance to herbicides occurs for high-efficient and persistent herbicides, which are characteristics that increase selection pressure.

Another favourable point of the proposed scale of grades for herbicide efficiency is that it can be used, regardless of the symptoms caused by different herbicides. Christoffoleti and Nicolai (2016), Oliveira Jr.; Constantin; Inoue (2011) and Kissmann (2000), reported symptoms of herbicides of several chemical groups and mechanisms of action on plants after their application.

Considering these factors, the objective of this work is to propose a grade scale for evaluations in studies related to herbicides, which would be closer to the technical reality and have higher precision in the interpretations.

Material and methods

In order to construct the new grade scale, a herbicide efficacy rule described by Lorenzi (2000) was analyzed and compared with the herbicide efficacy performed by percentage. For the validation of the results, two papers published in scientific articles were used (SILVA *et al.*, 2014 and SILVA *et al.*, 2018) to compare the results and the new grading scale.

The proposed scale of grades

Lorenzi (2000) considered the herbicide efficiency according to the classification shown in Table 1:

The proposed scale of grades for evaluation of herbicide weed control efficiency is presented in Table 2.

Table 1. Herbicide weed control efficiency, adapted from Lorenzi (2000). IFSULDEMINAS-Muzambinho. 2021.

Symbol	Description	Efficiency
H	Highly efficient	Above 95% control
E	Efficient	85 to 95% control
M	Moderately efficient	50 to 85% control
L	Little efficient	Less than 50% control
NE	Not efficient	0% control

Source: From the authors (2021).

Table 2. Scale of grades usually used for evaluations of herbicide efficiency and the proposed scale of grades for evaluation of herbicide weed control efficiency. IFSULDEMINAS-Muzambinho. 2021.

Control level (usually used scale)	Grade attributed (usually used scale)	Control level (proposed scale)	Grade attributed (proposed scale)
0 to 20% control	1	0 to 4% control	1
		5 to 9% control	2
		10 to 14% control	3
		15 to 19% control	4
21 to 40% control	2	20 to 24% control	5
		25 to 29% control	6
		30 to 34% control	7
		35 to 39% control	8
41 to 60% control	3	40 to 44% control	9
		45 to 49% control	10
		50 to 54% control	11
		55 to 59% control	12
61 to 80% control	4	60 to 64% control	13
		65 to 69% control	14
		70 to 74% control	15
		75 to 79% control	16
81 to 100% control	5	80 to 84% control	17
		85 to 89% control	18
		90 to 94% control	19
		95 to 99% control	20
		100% control	21

The transformation factor for the grade scale by % for 5-PPS is ("grade" / 5) + 1, except for the 100% grade which will be a direct grade for 21.

Source: From the authors (2021).

When using the proposed scale of grades, the results could be subjected to variance comparison test, such as the F test, and the means could be subjected to the Tukey, Dunnett, or Scott-Knott test, for example.

Comparison of scales

For this work, we selected some results of published works that tested the following evaluation systems:

A – Percentages (%);
B – 20-percentage point scale of grades;
C – 5-percentage point scale of grades.

The data collection consisted of a careful selection of different weeds (*Commelina benghalensis (Carl Von Linné)* and *Conyza canadensis (Carl Von Linné)*) at different days after application of herbicides to compare the statistical effect of the different evaluation systems.

The data were subjected to analysis of variance by the F test and the means were compared by the Tukey's test at 5% probability with values without transformation and values transformed to $[(x+0.5)^{0.5}]$, using the Sisvar 4.3 program (FERREIRA, 2011).

Results and discussion

The means for the effect of herbicides on *C. benghalensis* plants (SILVA *et al*., 2014) evaluated through percentages (1-PPS), 20-percentage point scale of grades (20-PPS), and 5-percentage point scale of grades (5-PPS) are shown in Table 3.

The variation of coefficients (VC%) found by Silva *et al*. (2014) were 46.97% for 5-PPS, which is high; 27.5% for 20-PPS, which is intermediate; and 65.5% for 1-PPS.

Besides the VC%, other results were similar between the evaluation method by percentages (1-PPS) and the proposed method (5-PPS); thus, in this case, the method 20-PPS did not allow to detect significant differences between the means found.

For Cargnelutti Filho *et al*. (2014), with the minimum significant difference generated by the media test, the variation index and the experimental variation coefficient, in this order, which are evaluated for experimental precision.

When the dada was transformed to $[(X+0.5)^{0.5}]$, the VC% was lower in all scales tested; however, only the methods 20-PPS and

5-PPS showed VC% below 20%. Moreover, only 5-PPS allowed to detect differences at 5% significance level between the treatments, with higher reliability already in the beginning of evaluation of the experiment.

For Ribeiro-Oliveira *et al*. (2018) the transformation of a data set is criticized because some researchers claim that the mathematical procedure can modify the original distribution of the data, making it a problem to interpret and discuss results at different scales than the original.

So it becomes necessary to create some ways to circumvent the data set transformation, maintaining statistical precision.

The means for the effect of herbicides on *C. canadensis* plants (SILVA *et al*., 2018) evaluated through 1-PPS, 20-PPS, and 5-PPS are shown in table 4.

According to the results shown in Table 4, the transformation of the data is not necessary and the method 5-PPS had lower coefficient of variation than the other methodologies of evaluation tested, although the difference

Table 3. Evaluation of herbicide weed control efficiency for *C. benghalensis* plants through percentages (1-PPS), 20-percentage point scale of grades (20-PPS), and 5-percentage point scale of grades (5-PPS), at 3 days after herbicide application (Silva *et al*., 2014). IFSULDEMINAS-Muzambinho. 2021.

Herbicide	1-PPS		20-PPS		5-PPS	
	X	$(X+0.5)^{0.5}$	X	$(X+0.5)^{0.5}$	X	$(X+0.5)^{0.5}$
1. Glyphosate	4.50 bc	2.22 bc	1.00 a	1.22 a	1.75 b	1.49 bc
2. Glyphosate + Metsulfuron-methyl	4.00 bc	1.98 c	1.00 a	1.22 a	1.50 b	1.40 bc
3. Glyphosate + Carfentrazone-ethyl	14.75 ab	3.81 ab	1.25 a	1.31 a	3.75 ab	2.03 ab
4. Glyphosate + Flumioxazin	22.50 a	4.66 a	1.50 a	1.40 a	5.50 a	2.41 a
5. Control	0.00 c	0.71 c	1.00 a	1.22 a	1.00 b	1.22 c
VC (%)	65.5%	28.6%	27.5%	8.82%	46.97%	17.07%

Means followed by same letters in the columns are not different by the Tukey's test at 5% significance.
Source: From the authors (2021).

Table 4. Evaluation of herbicide weed control efficiency for *C. canadensis* plants through percentages (1-PPS), 20-percentage point scale of grades (20-PPS), and 5-percentage point scale of grades (5-PPS), at 3 days after herbicide application. (Silva *et al*., 2018). IFSULDEMINAS-Muzambinho. 2021.

Herbicide	1-PPS		20-PPS		5-PPS	
	X	$(X+0.5)^{0.5}$	X	$(X+0.5)^{0.5}$	X	$(X+0.5)^{0.5}$
1. Control	0.00 f	0.71 f	1.00 d	1.22 d	1.00 f	1.22 f
2. Glyphosate	40.00 e	6.36 e	2.00 c	1.58 c	9.00 e	3.08 e
3. Glyphosate + Carfentrazone-ethyl	80.00 b	8.96 b	4.25 b	2.18 b	17.00 b	4.18 b
4. Glyphosate + Saflufenacil	100.00 a	10.02 a	5.00 a	2.34 a	21.00 a	4.64 a
5. Glyphosate + Flumioxazin	65.00 d	8.07 d	3.75 b	2.06 b	14.00 d	3.80 d
6. Glyphosate + Metsulfuron-methyl	67.50 cd	8.24 cd	3.75 b	2.06 b	14.50 cd	3.87 cd
7. Glyphosate + Chlorimuron-ethyl	77.50 bc	8.82 bc	4.00 b	2.12 b	16.50 bc	4.12 bc
CV(%)	8.14%	4.16%	8.71%	3.68%	7.53%	3.63%

Means followed by same letters in the columns are not different by the Tukey's test at 5% significance.
Source: From the authors (2021).

between the variation of coefficients was little expressive (SILVA *et al*., 2018).

The results from the evaluations by the methods 1-PPS and 5-PPS were identical for the differentiation between the means of the treatments, showing that the proposed scale provides results closer to the reality than the method 20-PPS, and a higher statistical precision when compared to the interpretation by percentages (1-PPS).

It is also important to mention that we have several tools to improve the experimental precision, such as increasing the number of repetitions and plots in an experiment (LÚCIO *et al*., 2016), this new scale being one more resource to be used in herbicide efficacy tests for weed control when the coefficient of variation is too high, even when data transformation is used.

Conclusions

The use of the proposed scale of grades decreases the coefficient of variation of the analysis of variance, allowing the detection of significant differences between treatments with greater reliability. It results in a better interpretation of the technical reality of herbicide effects, and can be used in direct and indirect evaluations of herbicide effectiveness in selectivity tests, allowing the study of selection pressure on susceptible biotypes to herbicides.

Acknowledgments

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