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Soybean response to simulated dicamba drift

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Abstract - This study aimed to evaluate the effects of simulated dicamba drift on non-resistant soybean variety. The research was conducted at the Embrapa Soybean experimental station in Londrina, PR, Brazil. The following parameters were assessed: a) length of the main stem, b) number of branches, c) number of pods, d) number of pods per branch, d) number of total grains, f) total grain weight, g) weight of a thousand grains, h) grain index per pod, i) grain per plant index, j) weight per pod index, k) weight per plant index, and l) pod per branch index. Dicamba was applied in the stage of two to three trefoils (V3/V4) and R1/R2 stages at rates of 0.00, 0.02, 0.04, 0.08, 0.15, 0.30, 0.60, 1.20, 2.40, and 4.80 g a.e. ha^{-1} from 0.00 to 1.00% of the recommended dose of 480.00 g a.e. ha^{-1}. Generally, soybean injury increased with increasing rates. Three days after application (DAA), the visual damage was more severe at the V3 stage compared to R1 up to the dose of 0.60 g a.e. ha^{-1}. Higher rates led to greater sensitivity at R1 stage. Subsequent evaluations at 7, 14, 21, 28, 35, and 42 DAA showed that application at R1 stage was more sensitive to phytotoxicity than at V3. Yield was mostly unaffected up to a drift rate of 0.60 g a.e. ha^{-1},but dropped sharply to the maximum rate at 1.00% of the regular dose (4.80 g a.e. ha^{-1}), to 100 % loss. The yield was not affected by the herbicide applied at V3.

Index terms: *Glycine max*; herbicide; phytotoxicity.

Resposta da soja à deriva simulada do herbicida dicamba

Resumo - Este trabalho teve como objetivo avaliar o efeito de deriva simulada do herbicida dicamba em variedade de soja não resistente a esse produto. A pesquisa foi conduzida na Fazenda Experimental da Embrapa Soja, em Londrina, PR. Foram avaliados os danos visuais de fitotoxicidade na cultura, bem como parâmetros de rendimento, altura da haste principal e das ramificações, número de vagens, peso de 1000 grãos, peso das vagens por planta, peso, número de grãos por vagem, número de ramificações por planta e acamamento. O dicamba foi aplicado nos estádios de dois a três trifólios (V3/V4) e R1/R2 nas doses de 0,00; 0,02; 0,04; 0,08; 0,15; 0,30; 0,60; 1,20; 2,40; e 4,80 g a.e. ha^{-1}, o que corresponde uma variação de 0,00 a 1,00% da dose recomendada de 480,00 g a.e. ha^{-1}. Em geral, os danos na soja aumentaram com o aumento

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das doses. A fitointoxicação visual foi maior no estádio V3, três dias após a aplicação (DAA) em comparação ao estádio R1, até a dose de 0,60 g a.e. ha^{-1}. Avaliações realizadas aos 7, 14, 21, 28, 35 e 42 DAA mostraram que a aplicação no estádio R1 foi mais sensível que a no V3 com relação à fitotoxicidade. Quanto a produtividade, nesta fase, praticamente não foi afetada até a dose de 0,60 g a.e. ha^{-1}, diminuindo bruscamente até a dose máxima de 1,00% da dose normal, 4,80 g a.e. ha^{-1}, o que resultou em uma perda quase total. Enquanto isso, a produtividade não foi significativamente afetada na aplicação no estádio V3.

Termos para indexação: *Glycine max*; herbicida; fitotoxicidade

Introduction

Among the significant factors impacting glyphosate-resistant soybeans (GRS) in Brazil are glyphosate-resistant weeds. *Conyza canadensis* (L.) has evolved resistance to glyphosate in GRSs worldwide. Glyphosate-resistant biotypes of *Conyza bonariensis* and *Lolium multiflorum* have been detected in Brazil. Other weeds such as *Chamaesyce hirta*, *Commelina benghalensis*, *Spermacoce latifolia*, *Euphorbia heterophylla*, *Richardia brasiliensis*, and *Ipomoea* spp. are tolerant or very difficult to control (Cerdeira et al., 2011).

To address glyphosate resistance, dicamba-resistant soybean cultivars have been introduced for effective weed control both pre- and post-emergence. However, this technology can also damage neighboring crops and native plants through herbicide drift or volatilization (Olszyk et al., 2015) and can increase sensitivity to other post-emergence herbicides (Brown et al., 2009). Studies suggest that low rates of dicamba might induce hormesis growth effects (Velini et al., 2010; Kniss, 2018).

This study aimed to evaluate the injury caused by simulated dicamba drift on susceptible soybean varieties growing near resistant ones.

Materials and methods

The experiment was carried out in Londrina, PR, Brazil, at the Embrapa Soybean experimental station (coordinates 23°11'30.33" S 51°10'57.80" W). The effects of simulated dicamba drift were evaluated on soybean cultivar BRS 543 RR. The soil, classified as a dystropherric Red Latosol, clay textural class, was fertilized at planting with 150 kg ha^{-1} of 00-20-20 NPK. The dicamba drift evaluation was based on the simulated rates listed in Table 1.

Table 1. Dicamba treatments applied at R1 and V3 soybean growth stages.

Rate (g. a.e. ha^{-1})	Percent of regular dicamba rate	Rate ($ml.ha^{-1}$) of commercial dicamba
4.80	1.00	10.00
2.40	0.50	5.00
1.20	0.25	2.50
0.60	0.13	1.25
0.30	0.06	0.63
0.15	0.03	0.31
0.08	0.02	0.16
0.04	0.01	0.08
0.02	0.005	0.04
0.00	0.00	0.00

The treatments were applied at two soybean growth stages: V3/V4 (21 days after emergence - DAE) and R1/R2 (39 DAE).

Experimental plots consisted of five rows of soybean, each 10 m long, with four rows sprayed over and a safety border between plots. The experimental design was a randomized block (RCB) with 11 treatments and four replications.

A visual injury scale based on percentage was used, where zero represented no injury and 100% represented total plant death. A damage threshold of 30% was set, beyond which productivity losses could occur. Evaluations began three days after application (3 DAA) and continued at seven-day intervals up to 42 DAA. Agronomic characteristics and yield components measured at harvest included: a) length of the main stem, b) number of branches, c) number of pods, d) number of pods per branch, d) number of total grains, f) total grain weight, g) weight of a thousand grains, h) grain index per pod, i) grain per plant index, j) weight per pod index, k) weight per plant index, l) pod per branch index.

A random sample of five plants per plot was measured for standing plant height. The length of the main stem in was measured in the laboratory due to apical bud death in some treatments. Grain moisture was corrected to 13% to account for humidity differences. Data were analyzed using analysis of variance, Tukey's test at 5% probability, and regression analysis.

Results and discussion

Dicamba was applied during the V3/V4 and R1/R2 stages at rates ranging from 0.00, 0.02, 0.04, 0.08, 0.15, 0.30, 0.60, 1.20, 2.40, and 4.80 g a.e. ha^{-1}, from 0.00 to 1.00% of the recommended dose of 480.00 g a.e. ha^{-1}. Generally, soybean injury increased with higher rates and exposure stages. Three days after application (DAA), the visual damage was more severe on the application at the V3 stage compared to R1 up to the dose of 0.60 g a.e. ha^{-1}. At higher rates, application at R1 became more sensitive than V3 (Figure 1).

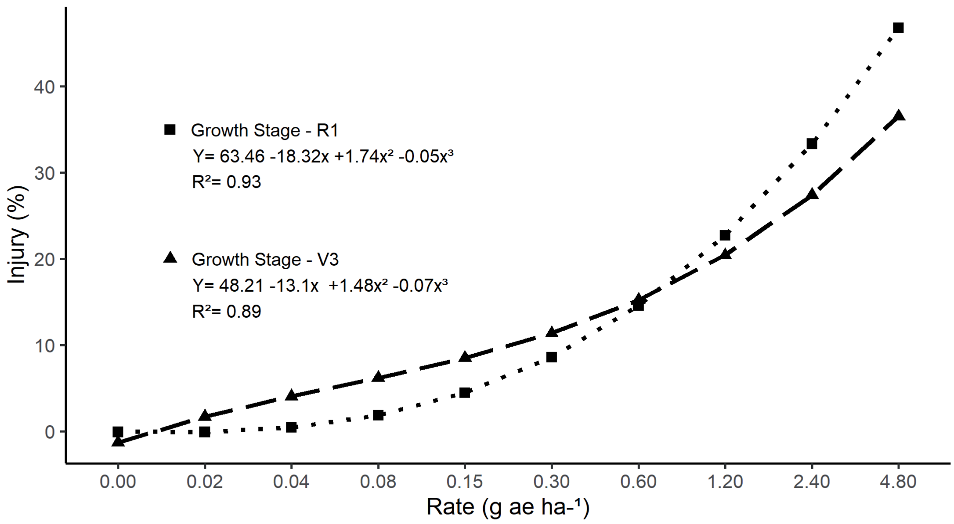

Figure 1. Dicamba injury at three days after application (3 DAA).

Evaluations at 7, 14, 21, 28, 35, and 42 DAA showed that application at stage R1 was more sensitive to phytotoxicity than V3 (Figures 2 to 7).

Dicamba injury was higher on application at R1 than at V3, especially towards the end of the evaluation period, consistent with similar findings from other studies (Griffin et al., 2013; Foster; Griffin, 2018; Kniss, 2018; Silva et al., 2018; Costa et al., 2020) (Figures 4 to 7).

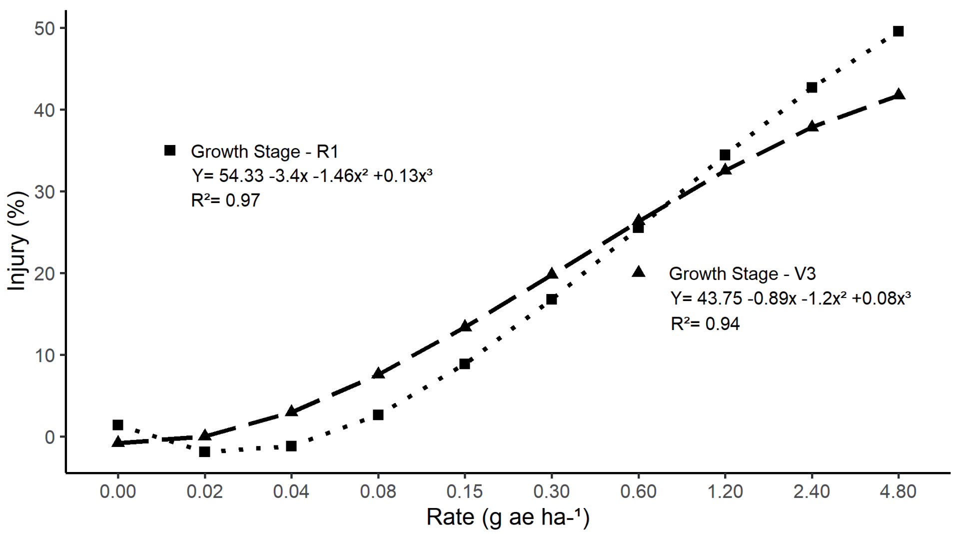

Figure 2. Dicamba injury at seven days after application (7 DAA).

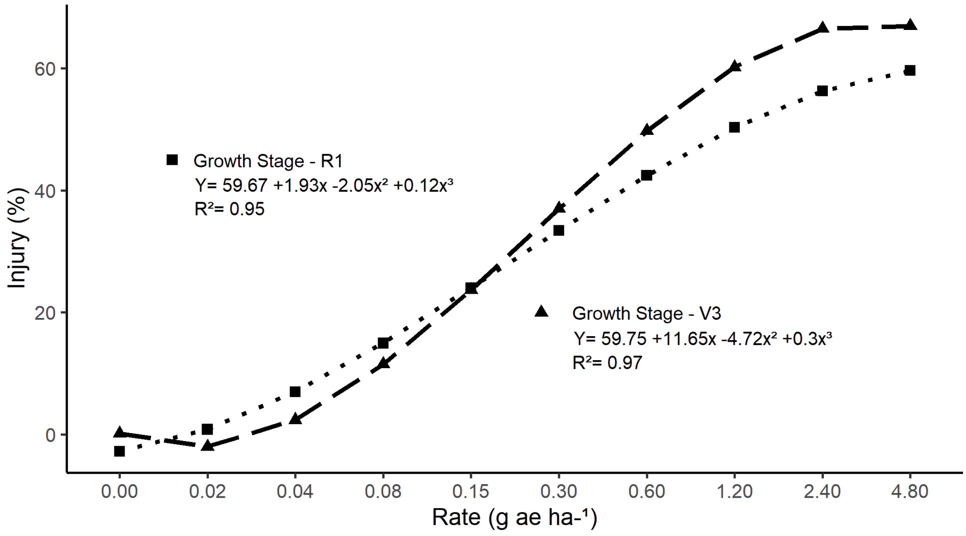

Figure 3. Dicamba injury at 14 days after application (14 DAA).

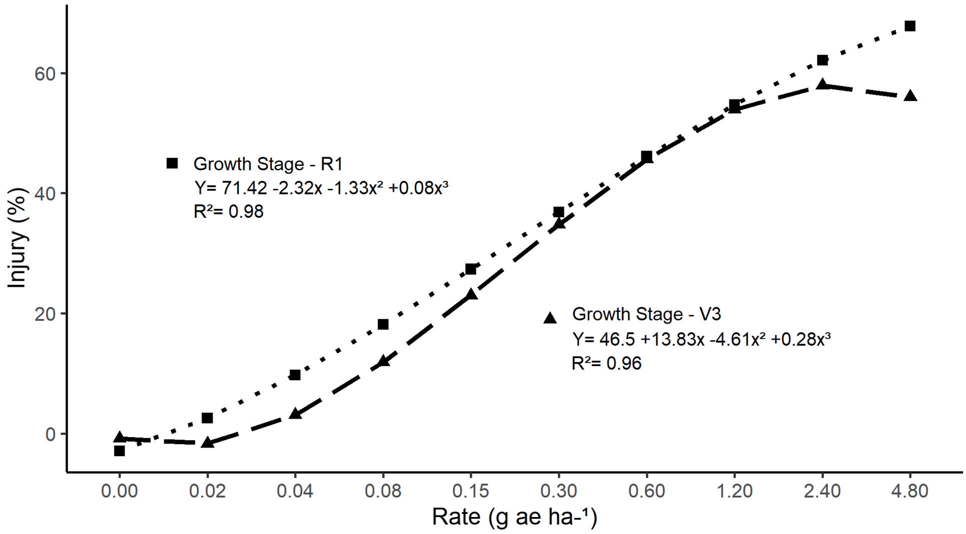

Figure 4. Dicamba injury at 21 days after application (21 DAA).

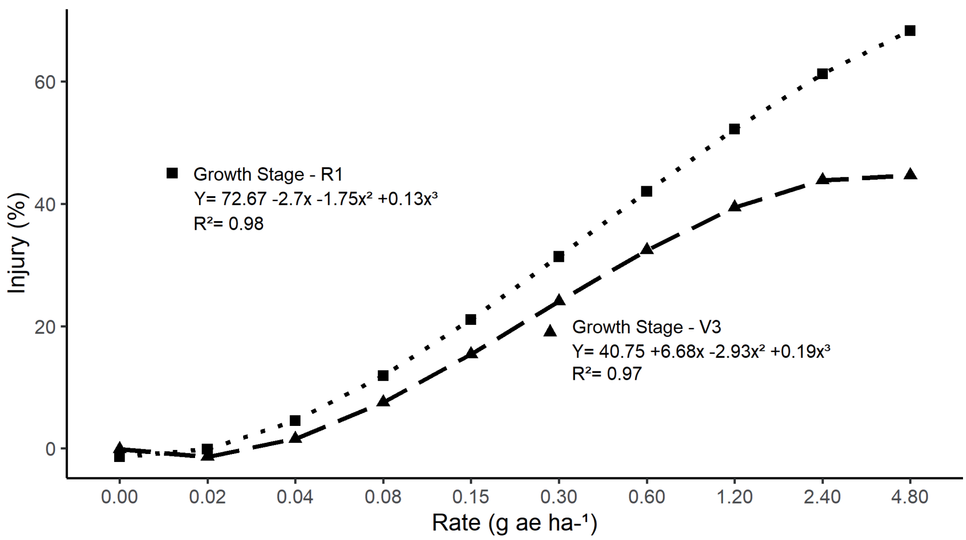

Figure 5. Dicamba injury at 28 days after application (28 DAA).

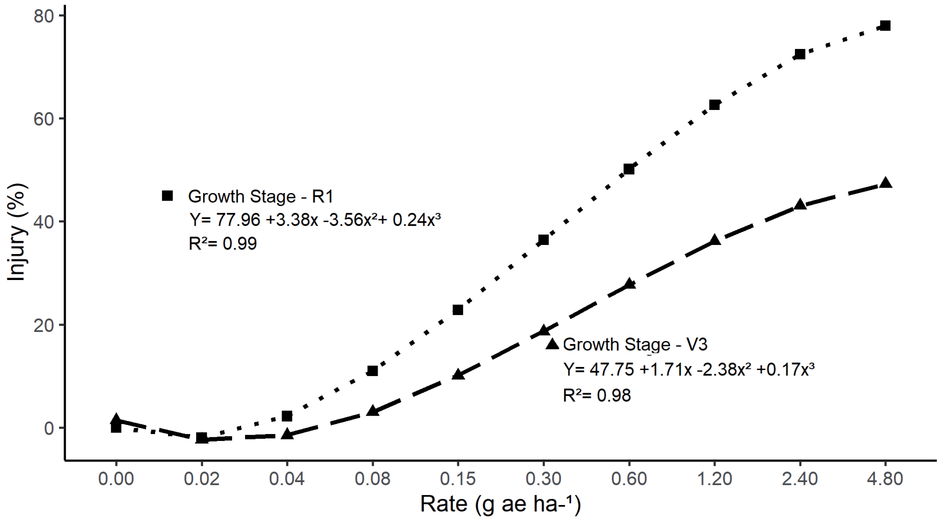

Figure 6. Dicamba injury at 35 days after application (35 DAA).

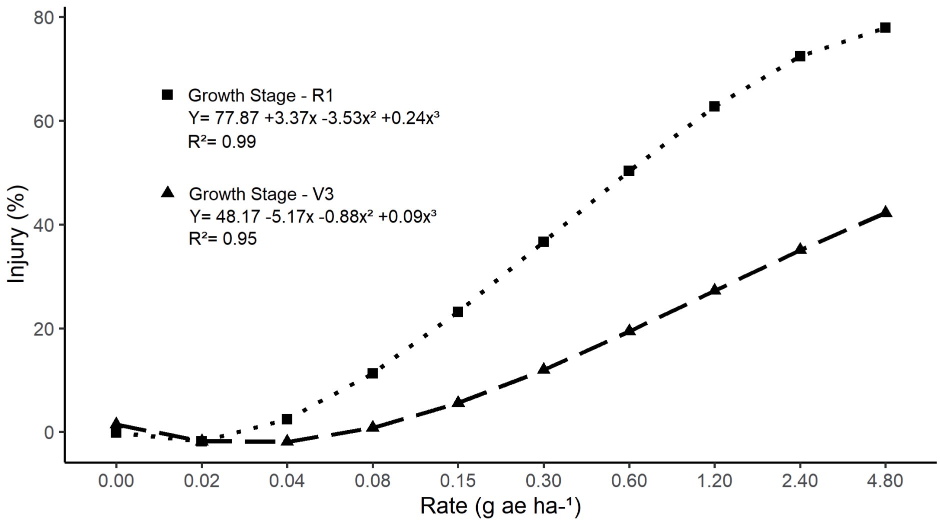

Figure 7. Dicamba injury at 42 days after application (42 DAA).

At the end of the crop cycle, agronomic parameters and yield components were assessed. The highest dicamba doses applied at both stages, V3 (1.20g a.e. ha^{-1}) and R1 (0.60 g a.e. ha^{-1}) caused death or growth paralysis of the main stem (Figures 8 and 9).

Dicamba application at V3 stage (Figure 10) with doses of 1.20 to 4.80 g a.e. ha^{-1} also reduced final plant height due to apical bud death. The control height was 119.9 cm, decreasing to approximately 90 cm in the three highest rates on application at the V3 stage (Figure 10). A similar pattern was observed in the R1 stage (Figure 11) but with a more abrupt height reduction, from 129.5 cm in the control to 41.6 cm at 4.80 g a.e. ha^{-1} and 71.5 cm at 0.60 g a.e. ha^{-1}.

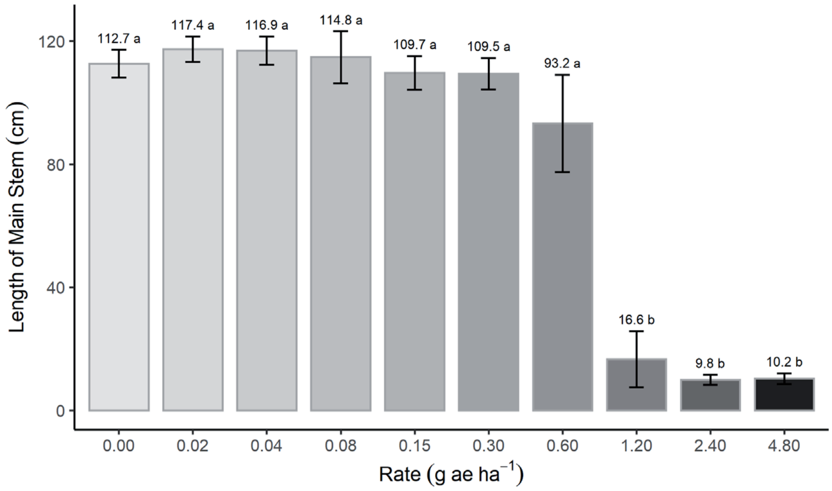

Figure 8. Length of main stem on application at V3 stage.

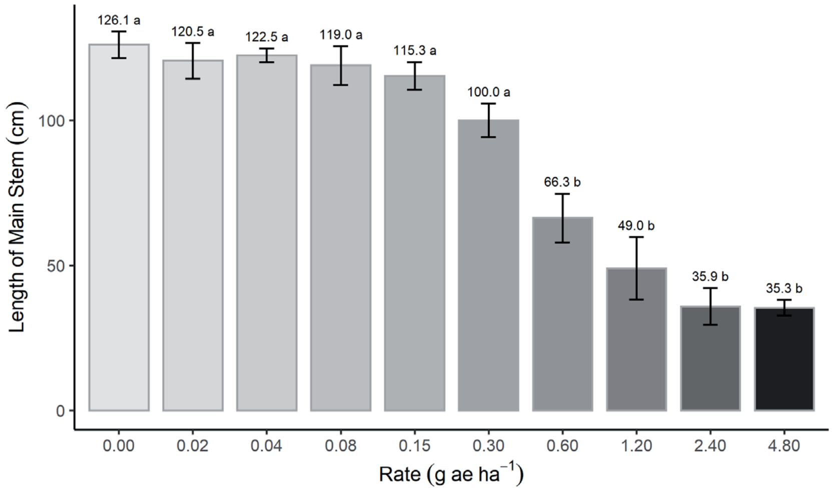

Figure 9. Length of main stem on application at R1 stage.

At higher rates, herbicide application affected final height in both stages, with more severe effects in R1 (Figures 10 and 11).

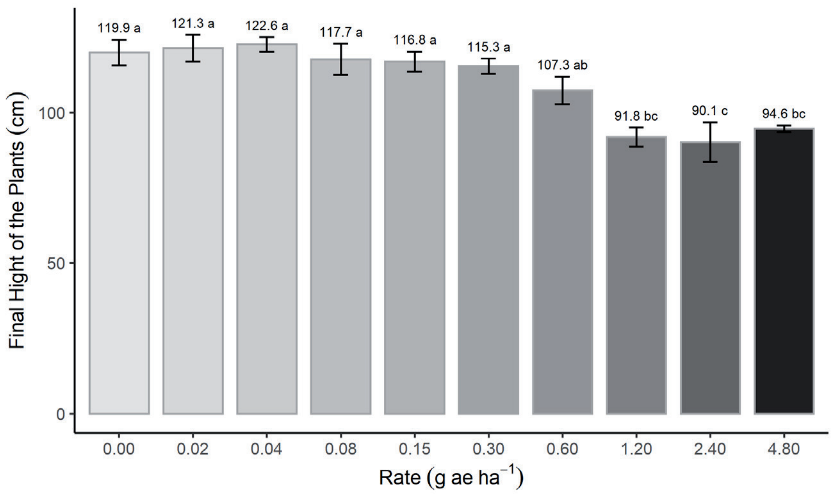

Figure 10. Final height on application at V3 stage.

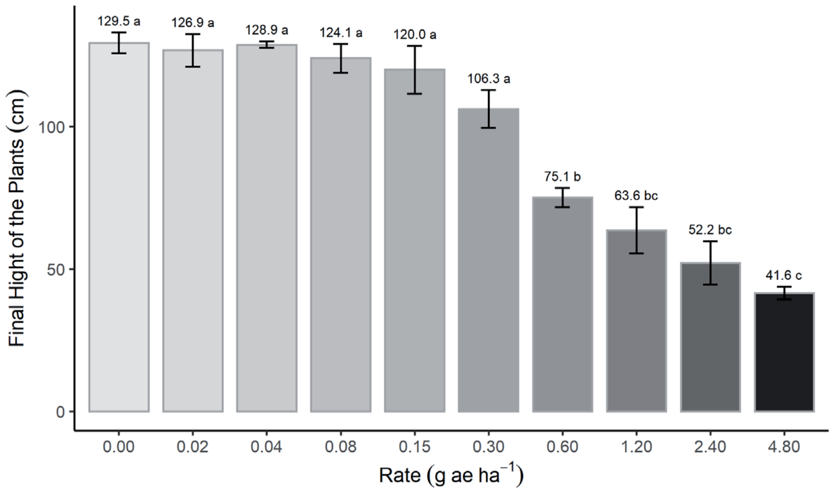

Figure 11. Final height on application at R1 stage.

At the end of the crop cycle, with the two highest doses applied in V3, there was a greater degree of lodging (Figure 12). There was no effect on application at the R1 stage.

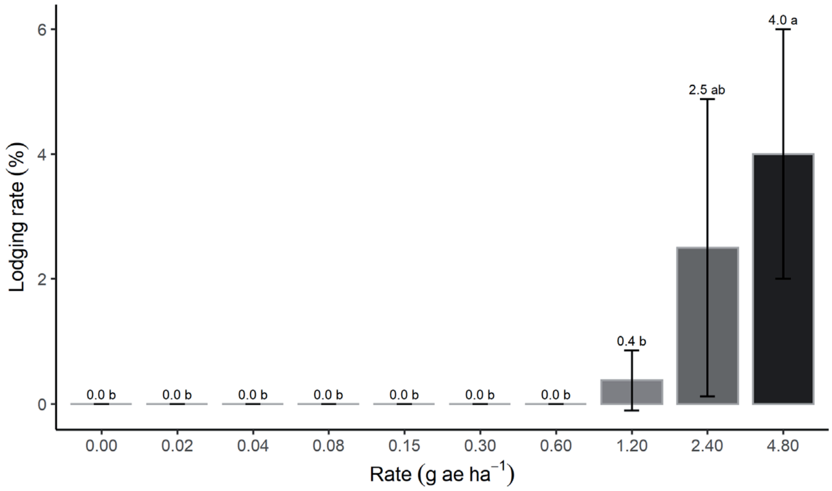

Figure 12. Lodging rate on application at V3 stage.

There was a relationship between stem branching and death or paralysis of the apical bud (Figures 8 and 9). Dicamba also stimulated the growth of lateral branches. The number of branches increased significantly in both applications at V3 and R1 stages at higher doses compared to the control, indicating a plant response to overcome herbicide damage (Figures 13 and 14).

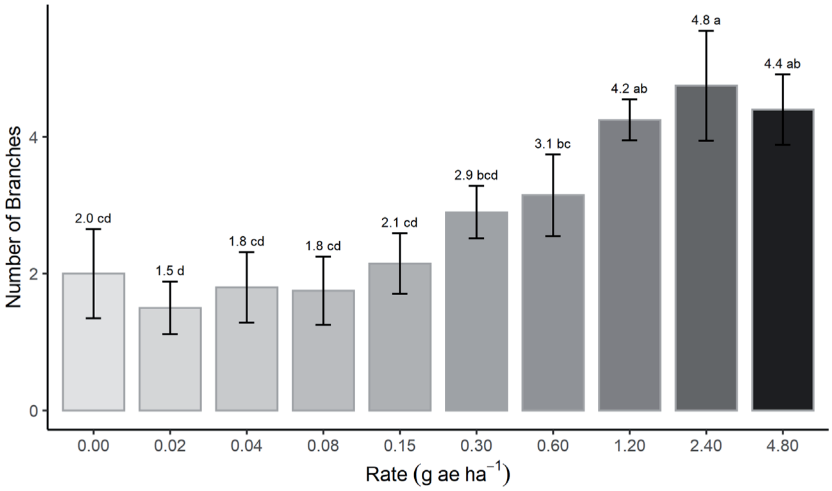

Figure 13. Number of branches on application at V3 stage.

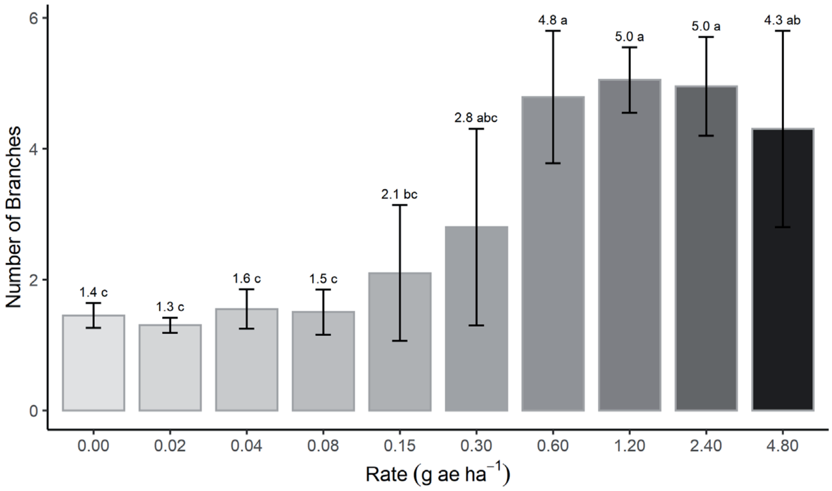

Figure 14. Number of branches on application at R1 stage.

In V3 applications, the number of pods per plant increased with doses above 1.20 g a.e. ha^{-1} (Figure 15), while in this same parameter, no significant differences were observed in R1. At the same time, the number of seeds per pod decreased with increasing doses (Figure 16), suggesting that yield compensation occurred in the V3 application.

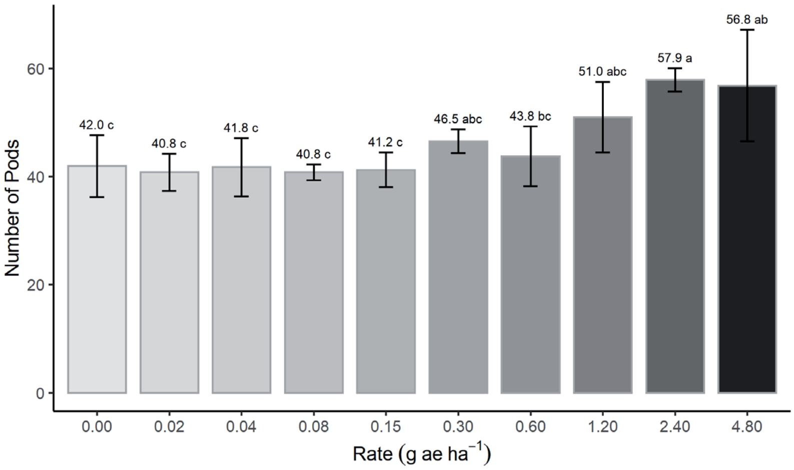

Figure 15. Number of pods per plant on application at V3 stage.

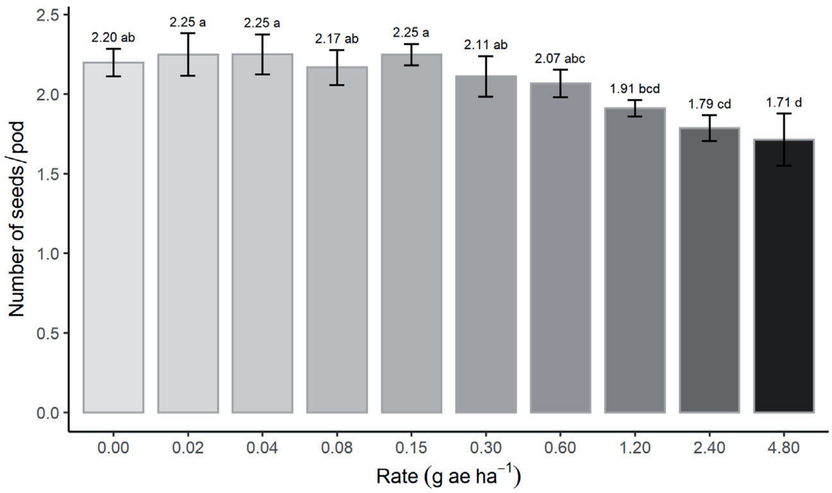

Figure 16. Number of seeds per pod on application at R1 stage.

The number of pods per branch varied in applications at both stages, with significant differences starting from 0.60 g a.e. ha^{-1} in R1 (Figures 17 and 18).

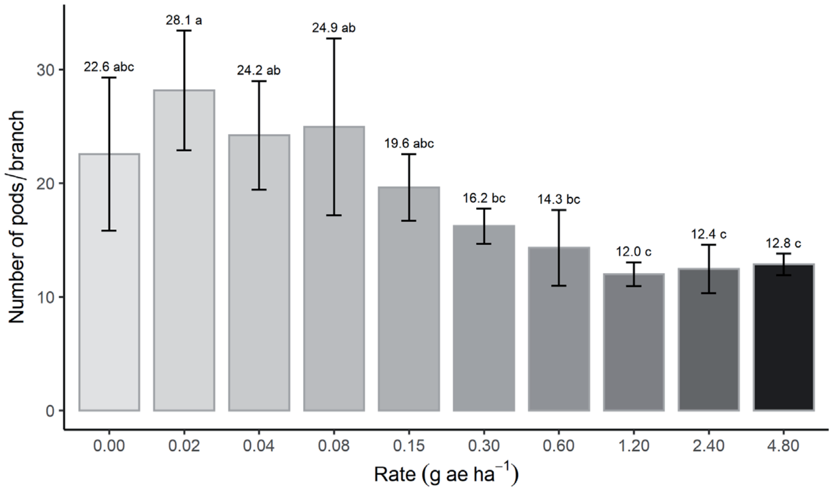

Figure 17. Number of pods/branch on application at V3 stage.

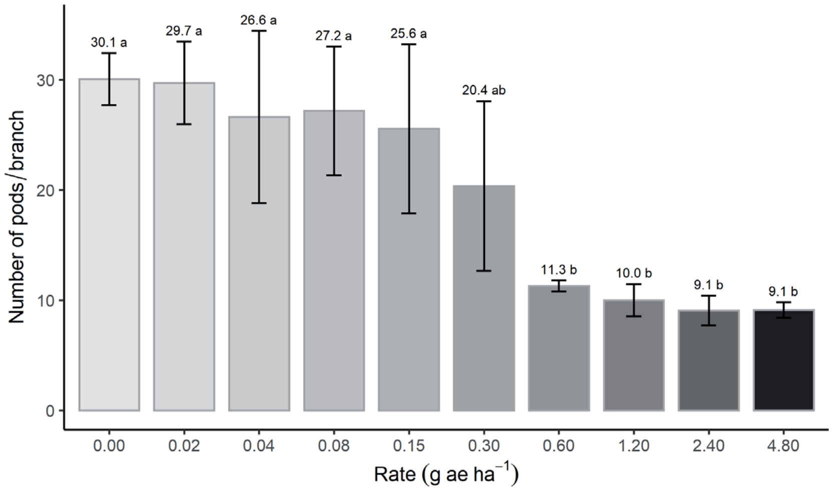

Figure 18. Number of pods/branch on application at R1 stage.

The weight of a thousand seeds on application at V3 decreased at doses higher than 0.60 g a.e. ha^{-1}, from 205 g in the control to 168.9 g at 4.8 g a.e. ha^{-1} (Figure 19), but final yield was not affected. In application at R1, no significant differences in seed weight were found, but yield was affected.

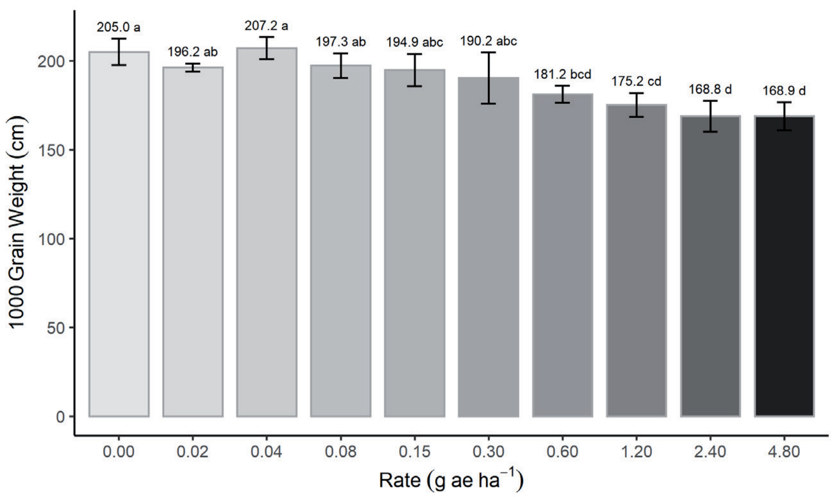

Figure 19. 1000 seeds weight g on application at V3 stage.

When dicamba was applied during V3, the yield was not affected by the herbicide (data not shown due to no statistical difference). The average yield was from 3170.7 kg ha^{-1} in treatment one, to 3194.7 kg ha^{-1} in the control (without product application), which shows that the plant had time for recovery. However, with the application at R1, the yield dropped from 3021.5 to 1972 kg ha^{-1} with 4.8 g a.e. ha^{-1} of herbicide (Figure 20), with an average of 2881.08 kg ha^{-1}.

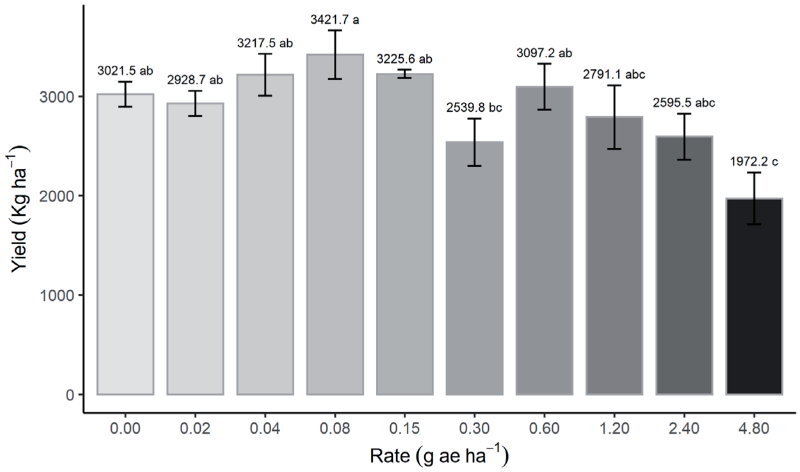

Figure 20. Yield on application at R1 stage.

Data interpretation indicates that dicamba can cause significant visual phytotoxicity and physical alterations, with recovery and compensation capacities higher in application at V3 than at R1. The application at R1 stage showed more pronounced effects on main stem length, final height, lateral branches, number of seeds per pod, pods per branch, and yield (Table 2).

Table 2. Summary of the effects of dicamba at selected soybean maturity stages.

	V3 Stage	R1 Stage
Length of main stem	Yes	Yes
Final height	Yes	Yes
Lodging	Yes	No
Lateral branches	Yes	Yes
Pods per plant	Yes	No
Seeds per pod	No	Yes
Pods per branch	Yes	Yes
1000 grain weight	Yes	No
Yield	No	Yes

Conclusion

Soybean is highly sensitive to dicamba, exhibiting severe visual injury symptoms. However, plants can recover if exposed to the herbicide during the vegetative stage (V3). In contrast, exposure during the reproductive stage (R1) results in increased sensitivity, reduced recovery potential, and yield loss depending on the amount of herbicide received.

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