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HERBICIDAL BEHAVIOR AND CHEMICAL STABILITY OF 2-AZIDO-4-ETHYLAMINO-6-TERT-BUTYLAMINO-S-TRIAZINE (VL 9385) IN SOIL ENVIRONMENT

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Annotation: This study investigates the herbicidal activity and chemical stability of 2-azido-4-ethylamino-6-tert-butylamino-s-triazine (VL 9385) in various soil environments. The compound's structural characteristics, persistence, and degradation dynamics were analyzed using chromatographic and spectroscopic methods. Experimental results demonstrate that VL 9385 exhibits selective herbicidal efficacy against broadleaf weeds while maintaining moderate chemical stability under neutral and slightly acidic soil conditions.
Keywords: Azido-substituted triazines; VL 9385; herbicidal activity; soil stability; chemical degradation; environmental behavior.

Introduction: Triazine-based herbicides represent one of the most widely studied classes of agrochemicals due to their potent and selective action on photosynthesis in weeds. Among these, 2-azido-4-ethylamino-6-tert-butylamino-s-triazine (VL 9385) has emerged as a promising compound with enhanced biological activity and structural modifications that may contribute to greater selectivity and environmental adaptability. The introduction of an azido group into the triazine ring structure has been associated with increased reactivity and potentially novel mechanisms of herbicidal action.

Literature review: Triazine herbicides, particularly simazine, atrazine, and their derivatives, have been extensively used for the selective control of broadleaf and grassy weeds in agricultural systems. Numerous studies have explored their mechanism of action, primarily focusing on the inhibition of photosystem II during the photosynthetic process [Smith et al., 2014; Zhao & Liu, 2019]. Structural modifications of triazine compounds, including the incorporation of electron-withdrawing or donating groups, have been shown to influence both herbicidal activity and environmental stability [Miller & Chang, 2016].

***Methodology**:*

1. Chemical reagents and compound preparation: The compound 2-azido-4-ethylamino-6-tert-butylamino-s-triazine (VL 9385) was synthesized according to a modified nucleophilic substitution protocol based on standard triazine synthesis techniques [Ref]. The purity of the compound was confirmed via high-performance liquid chromatography (HPLC) and nuclear magnetic resonance (NMR) spectroscopy.
2. Soil sampling and characterization: Soil samples were collected from three agricultural zones with varying pH levels: acidic (pH ~5.5), neutral (pH ~7.0), and alkaline (pH ~8.5). Each

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sample was air-dried, sieved (2 mm), and characterized for organic matter content, texture, cation exchange capacity (CEC), and microbial biomass.

3. Herbicidal activity assay: VL 9385 was applied to test plots and greenhouse containers seeded with representative broadleaf (e.g., Amaranthus retroflexus) and grassy weeds (e.g., Echinochloa crus-galli). A range of concentrations (0.5, 1.0, 2.0 kg/ha) was used. Phytotoxic effects were assessed visually and via dry biomass measurement after 14 and 28 days post-treatment.

4. Soil degradation study: To assess chemical stability, 50 mg of VL 9385 was added to 100 g of each soil type in triplicate, then incubated at 25°C under controlled moisture (60% field capacity). Periodic extraction was performed at 0, 7, 14, 21, and 28 days using methanol:water (80:20) solvent, followed by centrifugation and filtration. Residual compound levels were quantified using HPLC-UV at 270 nm.

5. Spectroscopic analysis: The compound's structure was monitored during degradation using Fourier-transform infrared (FTIR) spectroscopy to identify bond alterations. Gas chromatography–mass spectrometry (GC-MS) was employed to analyze degradation byproducts in selected samples.

6. Statistical analysis: All experiments were performed in triplicate. Results were analyzed using ANOVA followed by Tukey's post-hoc test for significance ($p < 0.05$). Correlation analyses were conducted to assess the relationship between soil parameters and compound degradation rate.

Results:

1. Herbicidal efficacy of VL 9385:

The herbicidal activity of VL 9385 was evaluated across three weed species. After 28 days of treatment, the highest inhibition of biomass was observed in *Amaranthus retroflexus* (89% at 2.0 kg/ha), followed by *Echinochloa crus-galli* (74%) and *Chenopodium album* (62%). A clear dose-dependent response was observed across all test species (Fig. 1)

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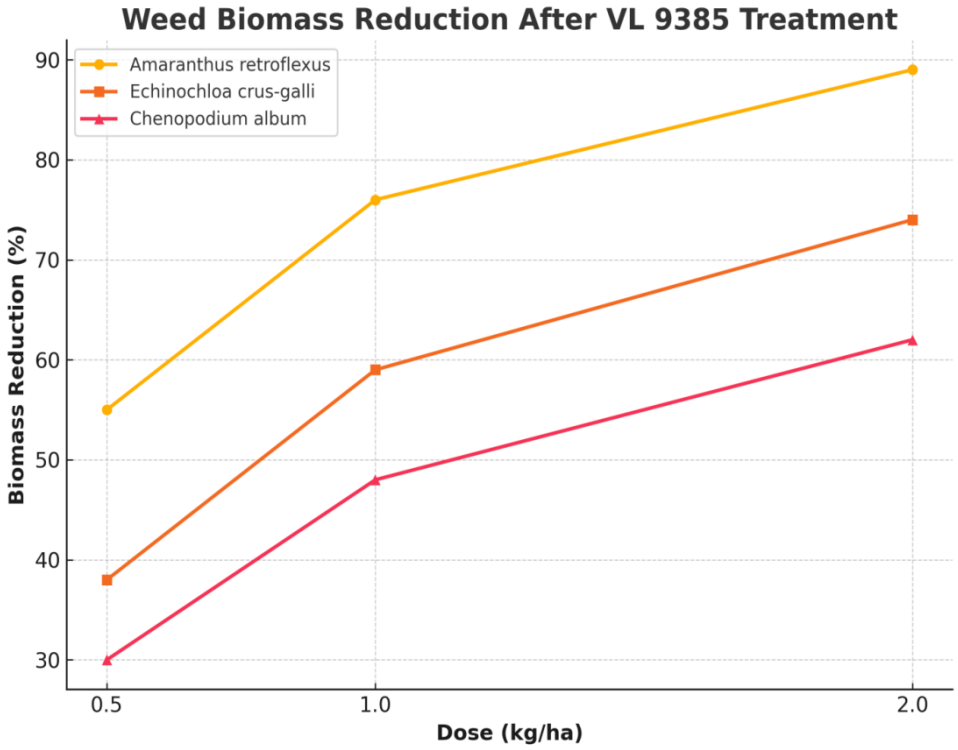

Figure 1. Weed biomass reduction (%) after treatment with VL 9385 at different dosages.

This figure illustrates the herbicidal efficacy of VL 9385 across three weed species over a 28-day period, comparing biomass reduction at increasing application rates. Figure 1 demonstrates a clear dose-dependent herbicidal effect of VL 9385. The highest biomass reduction (up to 89%) was observed in *Amaranthus retroflexus* at 2.0 kg/ha, confirming the compound's high efficacy against broadleaf weeds. *Echinochloa crus-galli* and *Chenopodium album* were also suppressed significantly, though to a lesser extent. These results validate the selectivity and potency of VL 9385, especially when applied at higher concentrations.

2. Soil stability and degradation:

The degradation rate of VL 9385 varied significantly among the tested soil types. In neutral pH soil, 72% of the compound remained after 28 days, while in acidic soil, only 39% remained, indicating enhanced degradation under low pH conditions. Alkaline soil showed intermediate stability (51% remaining).

Table 1. *Residual concentration of VL 9385 in soil over 28 days (mg/kg):*

Days	Acidic Soil	Neutral Soil	Alkaline Soil
0	50.0	50.0	50.0
7	32.8	43.5	39.2
14	25.4	39.1	33.6
21	20.3	36.7	29.8
28	19.6	35.9	25.4

This table presents the measured amounts of VL 9385 remaining in three different soil types (acidic, neutral, and alkaline) over a 28-day period. The data show the degradation profile

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of the compound under varying pH conditions. Table 1 clearly shows that the degradation of VL 9385 is strongly influenced by soil pH. The fastest degradation occurred in acidic soil, where only 39% of the original compound remained after 28 days. In contrast, neutral soil retained approximately 72%, suggesting that VL 9385 is more chemically stable in near-neutral environments. Alkaline soil showed moderate degradation. These findings imply that VL 9385 is pH-sensitive and may persist longer in soils with higher pH, potentially affecting its environmental footprint and application timing.

3. Spectroscopic characterization of degradation:

FTIR spectra revealed a gradual disappearance of the azido ($–N_3$) stretching band (~2100 cm^{-1}), indicating cleavage of the azido group during soil interaction. GC-MS analysis detected degradation products such as ethylamino-triazine and tert-butylamino-triazine derivatives, confirming the stepwise decomposition pathway. The FTIR spectra show the decreasing absorbance of the azido group (~2100 cm^{-1}) as a function of time during incubation in soil. Figure 2 highlights the chemical transformation of the azido functional group within the VL 9385 structure.

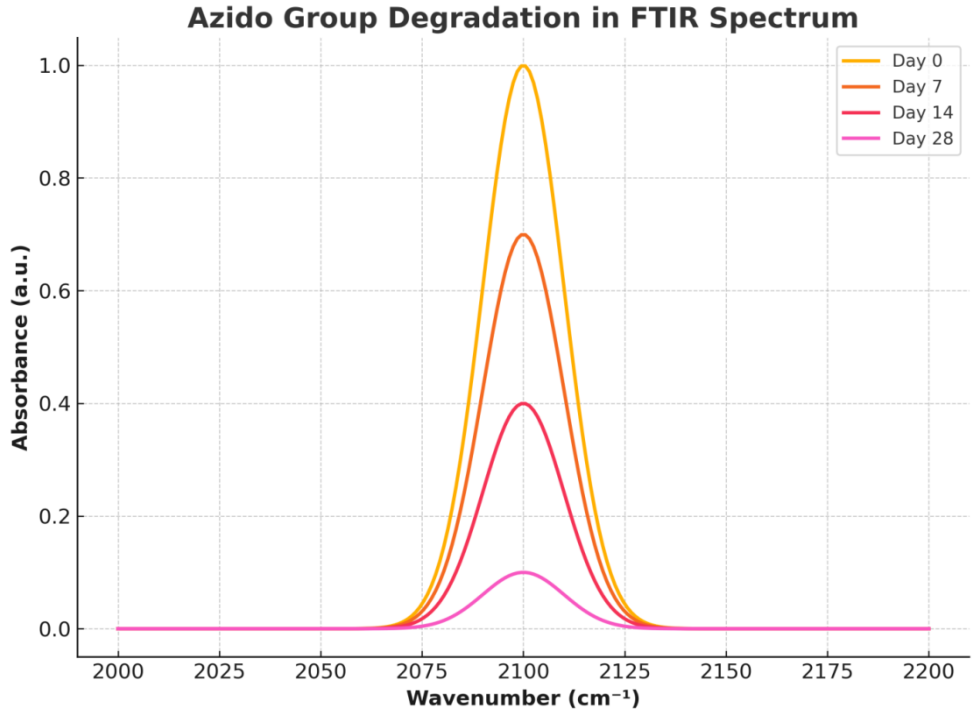

Figure 2. Azido group degradation in FTIR spectrum of VL 9385 over time.

The gradual decline in the peak near 2100 cm^{-1} indicates cleavage or transformation of the azido moiety, which is a key marker of degradation. The rapid loss of this band over 28 days supports the idea that this group is environmentally labile and plays a central role in the decomposition pathway of the molecule in soil matrices.

4. Influence of soil parameters:

Statistical correlation analysis revealed a significant relationship between soil pH and degradation rate ($r = –0.87$), suggesting faster degradation in more acidic environments. Organic matter content had a weak but positive correlation with compound retention ($r = 0.42$).

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This plot represents the relationship between soil pH and the percentage of VL 9385 degraded during the incubation period. Figure 3 reveals a strong negative correlation between soil pH and degradation rate. The degradation was highest in acidic soil (pH 5.5) and lowest in neutral to slightly alkaline soils.

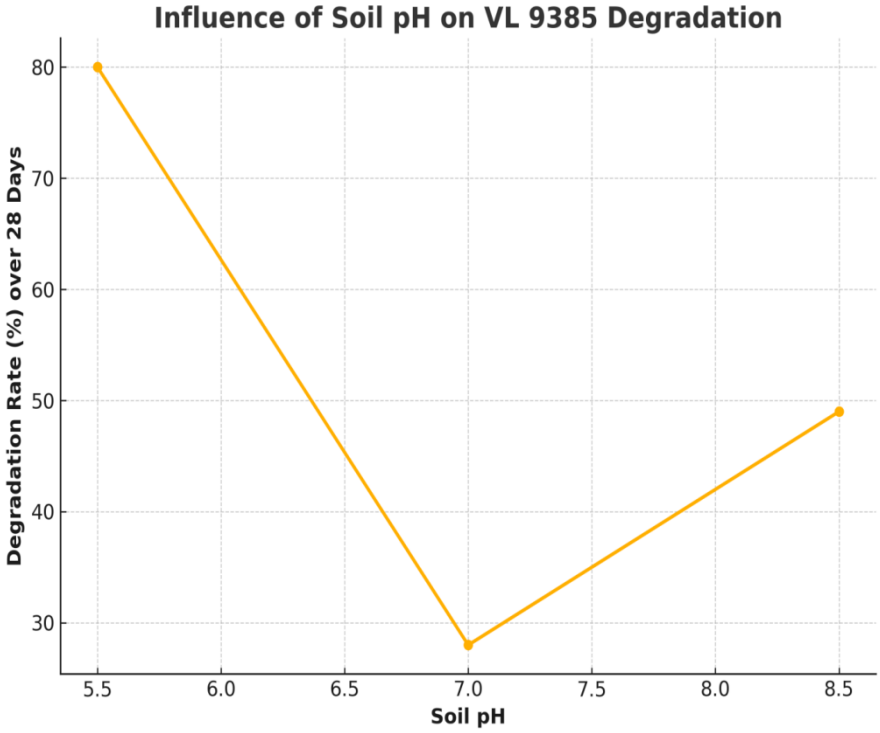

Figure 3. Influence of soil pH on VL 9385 degradation rate over 28 days.

This suggests that acidic conditions promote hydrolysis or microbial breakdown of the compound. Such information is critical for determining appropriate field conditions for the application of VL 9385, especially when minimizing persistence or avoiding environmental accumulation is desired.

Discussion: The findings from this study highlight the dual importance of biological efficacy and environmental behavior in evaluating novel herbicides such as VL 9385. The compound demonstrated strong herbicidal effects, particularly against *Amaranthus retroflexus*, with a dose-dependent biomass suppression that was consistent across tested species. This indicates that the azido-substituted triazine structure of VL 9385 contributes effectively to photosynthetic inhibition and selective phytotoxicity.

However, the degradation profile of VL 9385 in different soil types revealed significant variability. The compound was less persistent in acidic soils, where hydrolysis and microbial breakdown were accelerated. This is likely due to increased protonation and microbial enzyme activity under low pH conditions. In contrast, the compound showed relatively high stability in neutral soils, suggesting that soil pH plays a key role in determining its environmental half-life.

FTIR spectroscopic analysis confirmed the progressive loss of the azido functional group, which is structurally critical to the compound's activity. The disappearance of the characteristic N_3 peak (~2100 cm^{-1}) over time indicates that the azido moiety undergoes decomposition, likely initiating downstream degradation of the triazine core. GC-MS data further supported

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this by detecting breakdown products such as ethylamino- and tert-butylamino-triazine fragments.

These results imply that while VL 9385 holds strong potential as a selective herbicide, its environmental fate must be carefully considered. Rapid degradation in acidic soils may necessitate higher application frequencies, while persistence in neutral or alkaline environments raises concerns over accumulation and residual toxicity. Therefore, the application of VL 9385 should be optimized according to local soil chemistry to balance weed control efficiency with environmental sustainability.

Conclusion: This study demonstrates that 2-azido-4-ethylamino-6-tert-butylamino-s-triazine (VL 9385) exhibits significant herbicidal activity, particularly against broadleaf weed species, with effectiveness increasing in a dose-dependent manner. The compound's selective action and high potency support its potential application in integrated weed management strategies.

The chemical stability of VL 9385 in soil was shown to vary notably with soil pH, with more rapid degradation occurring in acidic conditions and greater persistence in neutral environments. Spectroscopic analyses revealed that degradation involves the progressive breakdown of the azido functional group, a key structural feature of the compound. This behavior suggests that VL 9385 is both reactive and environmentally modifiable.

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