Evaluation of New Herbicides on the Physiological Response and Control of Chrozophora (*Chrozophora rottleri*)

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Abstract**—** *Chrozophora rottleri is an aggressive, competitive broadleaf weed commonly found in rainfed and irrigated cropping systems. Its rapid growth and high resource consumption significantly reduce the growth and productivity of main crops. Effective management requires a thorough understanding of how different herbicides affect its physiological processes. A field experiment was conducted during the Rabi season of 2014-15 at the Regional Agricultural Research Station (RARS), Lam Farm, Guntur. The study employed a Randomized Block Design (RBD) with ten herbicidal treatments: atrazine, alachlor, pendimethalin, 2,4-D Na salt, bispyribac, pyrithiobac, topramezone, Iris (a.i. mesosulfuron-methyl + iodosulfuron-methyl), ethoxysulfuron, and an untreated control. Herbicides were applied at their recommended field doses, and physiological observations were recorded at 14 and 21 Days After Sowing (DAS). Parameters assessed included plant height, leaf area, total chlorophyll content, photosynthetic rate, stomatal conductance, transpiration rate, and phytotoxicity symptoms. Results revealed significant variation among treatments for all measured traits. The untreated control showed the highest plant height (24.53 cm) and substantial leaf area (1141.0 cm²), indicating vigorous growth in the absence of herbicide stress. These values were statistically on par with those observed in plots treated with pendimethalin and pyrithiobac, suggesting minimal growth suppression by these herbicides. Chlorophyll content was highest in the control (1.375 mg g^{-1} fresh weight), followed closely by pendimethalin (1.352 mg g^{-1}) and bispyribac (1.348 mg g^{-1}). In stark contrast, topramezone (0.642 mg g^{-1}) and ethoxysulfuron (0.0 mg g^{-1}) caused severe chlorophyll degradation. Interestingly, photosynthetic rate was highest under alachlor (51.93 µmol m^{-2} s^{-1}) and bispyribac (50.91 µmol m^{-2} s^{-1}), while ethoxysulfuron completely inhibited photosynthesis. Phytotoxicity was most severe with ethoxysulfuron (score 10) and topramezone (score 9), causing plant mortality, whereas pendimethalin and pyrithiobac showed minimal visible injury (score 0). The study concludes that pendimethalin and pyrithiobac exert limited suppressive effects on the physiology of C. rottleri, while ethoxysulfuron and topramezone are highly effective and phytotoxic, causing complete physiological shutdown and plant death. These findings provide critical physiological insights for designing integrated and targeted weed management strategies against this problematic weed under field conditions.*

Keywords**— *Chrozophora rottleri, Herbicides, Physiological Parameters, Phytotoxicity, Photosynthesis, Weed Control, Integrated Weed Management.***

I. INTRODUCTION

Chrozophora rottleri is a troublesome broadleaf weed prevalent in both rainfed and irrigated agricultural ecosystems across India. Its competitive ability for essential resources—light, nutrients, and water—poses a significant threat to crop yields. Effective and timely weed management is therefore paramount for sustainable crop production and resource use efficiency. Among various control methods, chemical weed control via herbicides remains a cornerstone due to its efficacy, timeliness, and economic feasibility. However, herbicide effectiveness is highly variable, depending on factors such as the weed species, its growth stage, the herbicide's mode of action, application rate, and environmental conditions. Furthermore, non-target effects and the potential for developing herbicide resistance necessitate a judicious and science-based selection of herbicides (Chauhan & Abugho, 2013).

Traditional herbicides like atrazine, alachlor, pendimethalin, 2,4-D, and newer molecules like bispyribac and pyrithiobac have been widely used for broad-spectrum weed control. Concurrently, newer herbicides such as topramezone (an HPPD inhibitor), ethoxysulfuron (an ALS inhibitor), and pre-mixes like Iris (mesosulfuron-methyl + iodosulfuron-methyl) are being introduced. However, their specific physiological impact and efficacy on *Chrozophora rottleri* are not well-documented, particularly under field conditions in the Indian context. A detailed understanding of how these herbicides affect key physiological processes—photosynthesis, pigment synthesis, and transpiration—is crucial for predicting their efficacy and understanding the basis of weed susceptibility or tolerance (Grossmann & Ehrhardt, 2007; Heap, 2022).

This investigation was undertaken with the objective of evaluating the effect of a range of pre- and post-emergence herbicides on the growth and physiological performance of *Chrozophora rottleri*. The specific aim was to identify herbicides that effectively disrupt its physiology, leading to control, while also assessing their degree of phytotoxicity to understand their potential fit within integrated weed management (IWM) programs.

II. MATERIALS AND METHODS

2.1 Experimental Site and Design:

A field experiment was conducted during the Rabi season of 2014-15 at the Regional Agricultural Research Station (Lam Farm), Guntur, Andhra Pradesh. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The soil of the experimental site was a sandy loam with good drainage.

2.2 Weed Establishment and Treatments:

A pure stand of *Chrozophora rottleri* was raised by sowing its seeds in well-prepared field plots. Ten herbicidal treatments were imposed, including an untreated control. The herbicides, their active ingredients, and doses are listed below:

1. **T1:** Atrazine @ 1.0 kg a.i./ha
2. **T2:** Alachlor @ 1.0 kg a.i./ha
3. **T3:** Pendimethalin @ 1.0 kg a.i./ha
4. **T4:** 2,4-D Na salt @ 1.0 kg a.i./ha
5. **T5:** Untreated Control
6. **T6:** Bispyribac-sodium @ 25 g a.i./ha
7. **T7:** Pyrithiobac-sodium @ 100 g a.i./ha
8. **T8:** Topramezone @ 30 g a.i./ha
9. **T9:** Iris (Mesosulfuron-methyl 3% + Iodosulfuron-methyl 0.6%) @ 14.4 g a.i./ha
10. **T10:** Ethoxysulfuron @ 18.75 g a.i./ha

Herbicides were applied as post-emergence sprays using a knapsack sprayer when the weeds were at the 3-4 leaf stage.

2.3 Observations Recorded:

Data on growth and physiological parameters were recorded at 14 and 21 Days After Sowing (DAS) from five randomly tagged plants per plot.

- **Plant Height (cm):** Measured from the base to the apex of the main stem.
- **Leaf Area (cm^2):** Measured using a leaf area meter (Model: LI-3100C, LI-COR, USA).
- **Total Chlorophyll Content (mg g^{-1} fresh weight):** Estimated spectrophotometrically using the method of Arnon (1949).
- **Gas Exchange Parameters:** Measured between 10:00 AM and 12:00 PM on clear, sunny days using a portable photosynthesis system (LI-6400XT, LI-COR, USA).
    - Photosynthetic Rate (Pn; µmol CO_2 m^{-2} s^{-1})
    - Stomatal Conductance (gs; mmol H_2O m^{-2} s^{-1})

  - Transpiration Rate (E; mmol H_2O m^{-2} s^{-1})

- **Phytotoxicity Score:** Visual injury symptoms were scored on a scale of 0 to 10, where 0 = no injury, 5 = 50% plant mortality or injury, and 10 = complete plant death.

2.4 Statistical Analysis:

The collected data were subjected to Analysis of Variance (ANOVA) appropriate for a Randomized Block Design using the statistical software SPSS (Version 16.0). The treatment means were compared at a 5% level of significance using the Least Significant Difference (LSD) test.

III. RESULTS AND DISCUSSION

The application of different herbicides had a profound and statistically significant ($p<0.05$) influence on all measured growth and physiological parameters of *Chrozophora rottleri* (Table 1).

TABLE 1
EFFECT OF DIFFERENT HERBICIDES ON GROWTH AND PHYSIOLOGICAL PARAMETERS OF *CHROZOPHORA ROTTLERI* (MEAN OF 14 AND 21 DAS)

Treatments	Plant Height (cm)	Leaf Area (cm^2)	Total Chlorophyll (mg g^{-1} f.w.)	Photosynthetic Rate (µmol m^{-2} s^{-1})	Stomatal Conductance (mmol m^{-2} s^{-1})	Transpiration Rate (mmol m^{-2} s^{-1})	Phytotoxicity Score (0-10)
T1: Atrazine @ 1 kg a.i./ha	20.46	585.56	0.927	43.35	0.44	7.19	0
T2: Alachlor @ 1 kg a.i./ha	17.46	412.82	1.109	51.93	0.56	8.51	0
T3: Pendimethalin @ 1 kg a.i./ha	24.4	1652.66	1.352	49.85	0.56	8.3	0
T4: 2,4-D Na salt @ 1 kg a.i./ha	21.66	715.96	1.358	46.15	0.5	7.89	0
T5: Control (Untreated)	24.53	1141	1.375	48.5	0.48	7.49	0
T6: Bispyribac @ 25 g a.i./ha	17.4	398.53	1.348	50.91	0.54	8.41	0
T7: Pyrithiobac @ 100 g a.i./ha	22.93	1187.51	1.346	47.67	0.47	7.33	0
T8: Topramezone @ 30 g a.i./ha	5.46	0	0.642	0	0	0	9
T9: Iris @ 14.4 g a.i./ha	8.66	457.06	0.829	47.66	0.5	8.03	4
T10: Ethoxysulfuron @ 18.75 g a.i./ha	0	0	0	0	0	0	10
SEm±	0.95	24.35	0.04	0.59	0.008	0.14	-
LSD (p=0.05)	2.83	72.15	0.119	1.74	0.024	0.41	-
Coefficient of Variation (CV %)	9.1	22.3	5.9	2.5	3.2	3.5	-

Note: Phytotoxicity Score: 0 = No injury, 10 = Complete plant death.

3.1 Growth Parameters:

Plant height and leaf area are primary indicators of vegetative growth and competitive ability. The untreated control (T5) produced the tallest plants (24.53 cm), which was statistically on par with treatments receiving pendimethalin (T3; 24.40 cm) and pyrithiobac (T7; 22.93 cm). This indicates that these herbicides had minimal inhibitory effect on the vertical growth of *C. rottleri*. In contrast, ethoxysulfuron (T10) caused complete plant mortality (0 cm), followed by severe stunting in topramezone (T8; 5.46 cm) and Iris (T9; 8.66 cm) treatments. Similarly, the maximum leaf area was recorded under pendimethalin (1652.66 cm^2), significantly higher than the control (1141.00 cm^2), suggesting a possible hormetic or non-inhibitory effect. Pyrithiobac

(1187.51 cm²) also allowed considerable leaf expansion. Ethoxysulfuron and topramezone completely suppressed leaf development (0 cm²). These results align with the known mode of action; pendimethalin, a microtubule assembly inhibitor, primarily affects root growth and may have less immediate impact on established seedling shoot growth, while ALS and HPPD inhibitors like ethoxysulfuron and topramezone rapidly halt new growth (Senseman, 2007).

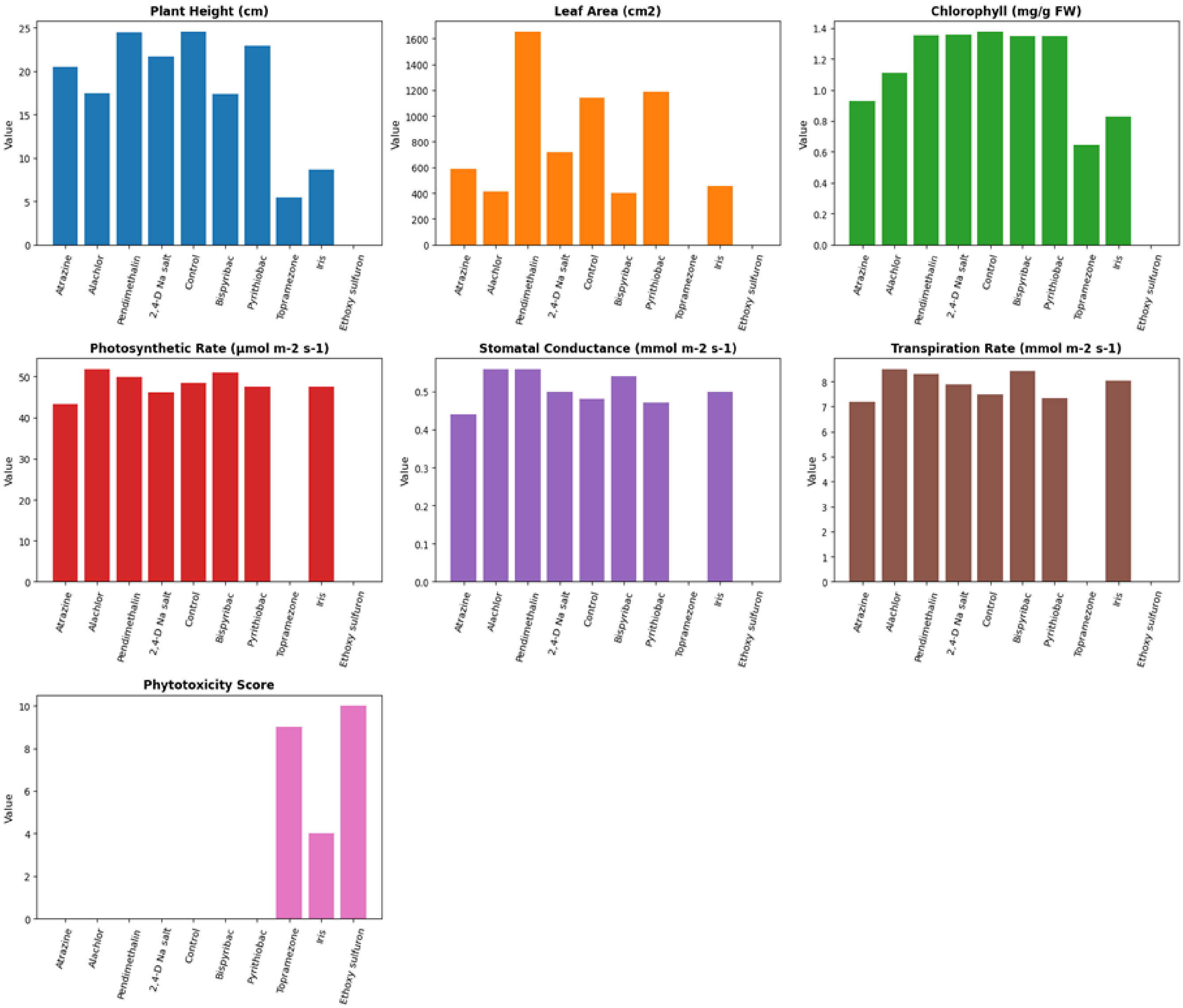

FIGURE 1: Effect of different growth parameters on the different growth parameters

3.2 Physiological Parameters:

Chlorophyll content is a direct indicator of photosynthetic potential. The control plants maintained the highest chlorophyll content (1.375 mg g^{-1}). Pendimethalin (1.352 mg g^{-1}), bispyribac (1.348 mg g^{-1}), and pyrithiobac (1.346 mg g^{-1}) were statistically comparable to the control, showing no significant bleaching or chlorophyll degradation. Conversely, topramezone, an HPPD inhibitor that disrupts carotenoid synthesis leading to photobleaching, significantly reduced chlorophyll (0.642 mg g^{-1}). Ethoxysulfuron resulted in complete chlorophyll loss (0.0 mg g^{-1}), consistent with its lethal effect. The pattern for photosynthetic rate (Pn) was intriguing. The highest Pn was recorded in alachlor-treated plants (51.93 µmol m^{-2} s^{-1}), followed by bispyribac (50.91 µmol m^{-2} s^{-1}) and pendimethalin (49.85 µmol m^{-2} s^{-1}), all surpassing the control (48.50 µmol m^{-2} s^{-1}). This transient increase could be a stress response or related to altered stomatal behavior before the onset of severe injury. As expected, photosynthesis was completely arrested (0 µmol m^{-2} s^{-1}) by ethoxysulfuron and topramezone. Stomatal conductance and transpiration rate followed a similar trend, being highest in alachlor and bispyribac treatments and completely inhibited by the most effective herbicides.

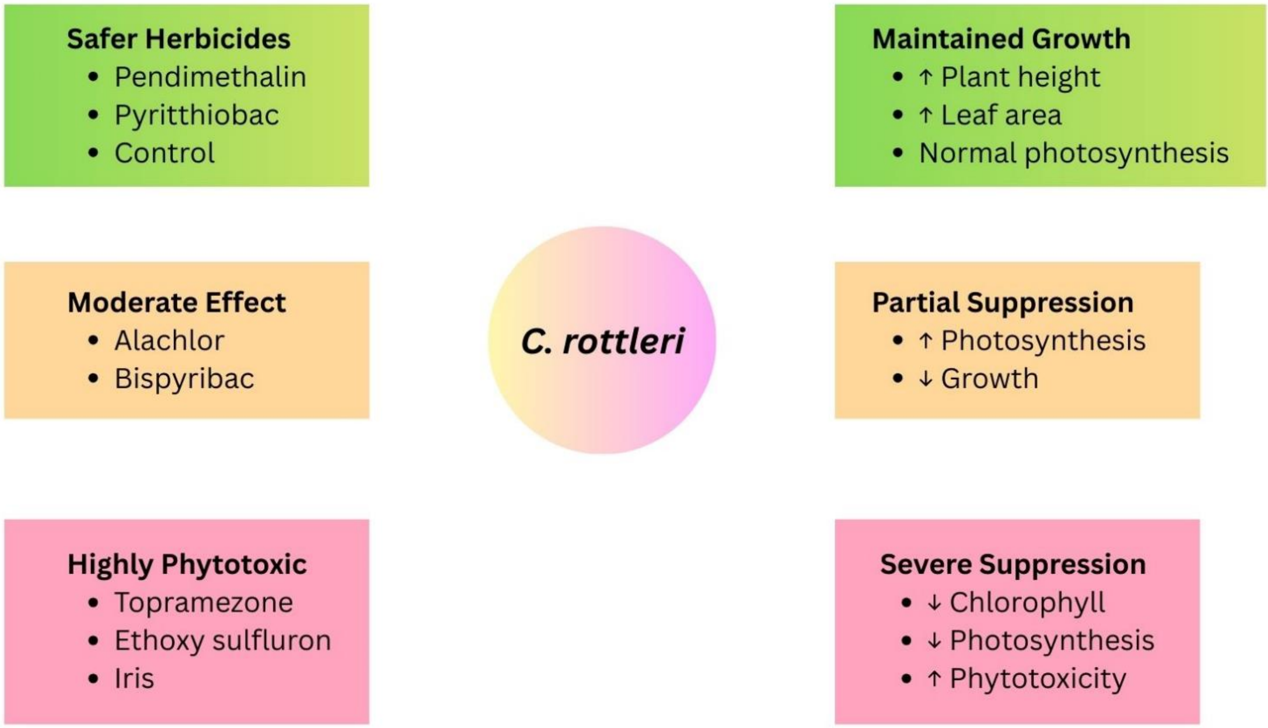

FIGURE 2: Graphical Abstract: Herbicide Effects on Crozophora rottlerin

FIGURE 3: Field view of the experiment

3.3 Phytotoxicity:

Visual phytotoxicity scoring provided a clear efficacy ranking. Ethoxysulfuron (score 10) and topramezone (score 9) exhibited extreme phytotoxicity, leading to severe chlorosis, necrosis, and plant death. Iris showed moderate injury (score 4). All other herbicides, including pendimethalin, pyrithiobac, atrazine, and 2,4-D, showed no visible phytotoxicity symptoms (score 0) on *C. rottleri*, indicating either tolerance or insufficient absorption/translocation at the applied dose for this species.

FIGURE 4: Effect of different chemicals on growth

3.4 Coefficient of Variation (CV):

The CV ranged from 9.1% for photosynthetic rate to 32.7% for plant height, indicating acceptable to moderate experimental precision. The LSD values confirmed that the observed differences among treatments for all parameters were statistically significant.

The findings are consistent with previous reports. Grossmann and Ehrhardt (2007) documented that HPPD inhibitors like topramezone cause rapid bleaching and growth arrest. The complete control by ethoxysulfuron aligns with the high sensitivity of many broadleaf weeds to ALS inhibitors (Heap, 2022). The minimal effect of pendimethalin on established seedlings of *C. rottleri* underscores the importance of application timing (pre-emergence) for this herbicide to be effective.

IV. CONCLUSION

The study conclusively demonstrates that herbicides have a differential and significant impact on the physiology of *Chrozophora rottleri*. Pendimethalin and pyrithiobac had minimal suppressive effects on growth and physiological functions, indicating that *C. rottleri* may possess tolerance or that these herbicides are not optimal for its post-emergence control. In contrast, ethoxysulfuron and topramezone were highly effective, causing severe physiological disruption—complete inhibition of chlorophyll synthesis, photosynthesis, and transpiration—leading to high phytotoxicity and plant mortality. Alachlor and bispyribac, while not severely inhibiting growth, showed interesting effects on gas exchange parameters that warrant further investigation. For effective integrated management of *Chrozophora rottleri* in field crops, post-emergence application of ethoxysulfuron or topramezone can be highly effective. However, their potential crop phytotoxicity must be carefully considered. Pendimethalin, if used, must be applied as a pre-emergence herbicide for effective control. These physiological insights provide a scientific basis for selecting and rotating herbicides in IWM strategies to manage this competitive weed sustainably.

Conflict of Interest

The authors declare no conflict of interest.

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