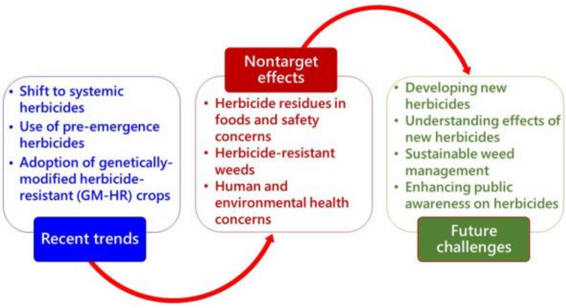
International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 2, Mar-Apr-2023, ISSN (Online): 2395-566X

One-Pot Multicomponent Reaction for Heterocyclic Synthesis by a Green Method and Their Herbicides Applications

Mr. S. S. Tiwade
sachintiwade7@gmail.com
Department of Chemistry, D. B. College, Bhokar, Nanded, Maharashtra, India

Abstract — A field experiment was conducted to find out the best combinations of pre- and post-emergence herbicides in maize for effective weed control and higher productivity at ICAR-Indian Institute of Maize Research, Ludhiana in 2021 and 2022. Results indicated that pre (PE)- and post-emergence (PoE) herbicide application, reduced the narrow-leaved weeds (NLW) and broad-leaved weeds (BLW) density from 62.41–91.46% and 55.53–82.11% respectively, compared to the weedy check. Among the PE, pyroxasulfone performed better than atrazine owing to selectivity towards maize with better weed control during both years. The density of Cyperus spp. was significantly reduced with halosulfuron PoE along with atrazine or pyroxasulfone PE over the years. A higher weed control efficiency (WCE) was found with pyroxasulfone followed by (fb) topramezone (90.4), while pyroxasulfone fb tembotrione (84.1) and atrazine fb topramezone (84.8) had similar WCE. Pyroxasulfone fb topramezone gave a 46.97% increase in grain yield over a weedy check. Pyroxasulfone fb topramezone and pyroxasulfone fb tembotrione resulted in higher net returns and B:C. Therefore, the application of pyroxasulfone as PE fb tembotrione as PoE or pyroxasulfone as PE fb topramezone as PoE may be recommended for better weed control and higher maize grain yield in NWPZ of India.

Keywords— Multicomponent reaction, one-pot synthesis, heterocycles, 2-amino-4H-pyran, green chemistry, biological activity, medicinal chemistry



I. INTRODUCTION

Heterocyclic compounds constitute one of the most important classes of organic molecules because heterocyclic rings occur extensively in pharmaceuticals, natural products, agrochemicals, dyes and functional materials. Nitrogen-, oxygen- and sulfur-containing heterocycles possess a wide range of biological properties and therefore continue to attract considerable attention in medicinal chemistry. Traditional synthesis of complex heterocyclic molecules often involves several individual reaction steps, isolation of intermediates, solvent consumption and repeated purification. Multicomponent reactions provide an alternative strategy in which three or more reactants participate in a convergent transformation to form a highly functionalized product in a single operation. Reviews of the field emphasize that this approach can reduce waste, energy consumption and synthetic effort while allowing rapid preparation of structurally diverse compounds. Recent research has particularly emphasized one-pot MCRs for medicinally relevant cyclic structures. A 2025 RSC Advances review covering MCRs reported since 2019 highlighted single-pot reactions that produce novel ring systems or substitution patterns under relatively mild conditions and noted their potential value in medicinal chemistry. Similarly, a 2025 European Journal of Organic Chemistry review described Ugi, Biginelli, Passerini and related MCRs as efficient approaches to nitrogen-, oxygen- and sulfur-containing heterocycles of pharmaceutical relevance.

1. Aim of the present work

The aim of this proposed research is to develop a simple, economical and environmentally preferable one-pot MCR methodology for the preparation of substituted heterocyclic compounds and to investigate their potential biological applications.

- To develop a one-pot three-component synthesis of substituted 2-amino-4H-pyran derivatives.
- To investigate a mild and green catalytic reaction system.
- To optimize catalyst loading, temperature, reaction time and solvent conditions.

- To characterize the synthesized compounds using spectroscopic techniques.
- To evaluate the compounds for selected antimicrobial and antioxidant activities.
- To establish preliminary structure–activity relationships (SAR)

II. IMPORTANCE OF HERBICIDES IN MODERN

Agriculture

Weeds are considered as a major obstacle in the modern farming system, as they reduce crop yield and quality, resulting in many billion dollars of crop losses annually (Abouziena and Haggag 2016). It is well documented that the losses caused by weeds have exceeded those from any category of agricultural pests, viz., insects, diseases, nematodes, rodents, etc. (Oerke 2006). Rao (2000) reported that the total annual losses of agricultural produce from weeds, insects, diseases, and other pests account for 45, 30, 20 and 5%, respectively. Globally, the estimated damage caused by weeds is around US $40 billion per year (Abouziena and Haggag 2016), which is over $26 billion in the USA alone, causing a major threat to food security (Delye et al. 2013). Consequently, herbicide use is the best way of controlling weed infestation in the agricultural farming system, offering easy application coupled with economic sustainability (Singh et al. 2020), quick action and efficient killing of approximately 90–99% of the targeted weeds (Delye et al. 2013). During the last century, herbicides became an unavoidable tool of agriculture, which allowed for a noticeable increase in crop yield to feed a rapidly growing human population (Carvalho 2017).

Accordingly, global herbicide consumption has drastically increased by many folds, contributing to 47.50% of the total pesticide usage (Singh et al. 2020). Nearly, two thousand herbicide compounds have been discovered and put into application for the management of weeds in different arable lands worldwide. It may either be applied to the soil during land preparation or directly to the foliage (Sherwani et al. 2015). Pre-emergence herbicides are applied to the soil surface to kill weeds before the seedling emergence (Preisler et al. 2020). Examples of pre-emergence herbicides include imazethapyr, isoxaflutole, metolachlor, and pendimethalin

(Mobli et al. 2020). Post-emergence herbicides are applied to weed seedlings that have already emerged and 2,4-D, mazethapyr, imazamox, and metribuzin are examples of post-emergence herbicides (Taran et al. 2013). The diversified groups of herbicides (Table 1) help to eradicate different weed species without disturbing crop plants (Vats 2015). Herbicides can also be classified based on their mechanism of action and chemical family. The mode of action refers to the specific biochemical or physiological process targeted by the herbicide (Fig. 1), while the chemical family represents the structural similarity among herbicides. A detailed classification based on the mode of action and chemical class is provided in Table 2. Also, herbicides are widely used as plant growth regulators in crops, gardens, and lawns (Sack et al. 2015). For instance, lower amounts of glyphosate can stimulate plant growth (the effect is termed hormesis), helps to ripen sugarcane and inhibits rust diseases in glyphosateresistant wheat and soybean (Velini et al. 2010). In recent

years, farmers rely more on herbicides in agricultural farming due to increased labour wages and sometime unavailability of agricultural labour. Thus, herbicides became a crucial component for controlling undesirable noxious weeds in modern agriculture.

Recent trends in weed management

Recent trends in herbicide usage have been a subject of significant interest in the agricultural community over the past decade. However, the mode of action and human and environmental health effects of the formulations differ based on the chemical groups (Ozkara et al. 2016). The recent trends in herbicide usage suggest a gradual decline in the overall volume of herbicides, accompanied by a shift towards more specific and targeted herbicide formulations (Damalas and Koutroubas 2018; Cech et al. 2022). This shift is largely attributed to increased awareness of the potential ecological and health risks associated with indiscriminate herbicide application (Devi et al. 2022). Additionally, advancements in precision agriculture technologies have played a crucial role in facilitating more efficient and targeted herbicide use (Kendall et al. 2022). These findings provide valuable insights for Increased use of pre-emergence herbicides

In recent years, there has been a noticeable shift in usage towards pre-emergence herbicides. Pre-emergence herbicides are applied to the soil before the crop emerges, targeting weed seeds and seedlings in the soil, and these herbicides can effectively suppress weed growth before they emerge, and provide better weed control compared to postemergence herbicides (Cioni and Maines 2010). This trend has gained traction due to several advantages offered by pre-emergence herbicides, such as increased effectiveness, reduced herbicide resistance, preventing weed from competing with crops for nutrients, water and light, and improved crop safety (Zimdahl 2018). Furthermore, herbicide resistance is a major concern in modern agriculture, where weeds develop genetic resistance to commonly used herbicides, by incorporating pre-emergence herbicides into weed management strategies, farmers can diversify their herbicide modes

of action, reducing the risk of herbicide resistance development and preserving the efficacy of herbicides for longer periods (Cioni and Maines 2010; Gage et al. 2019). Pre-emergence herbicides are typically applied before the crop has emerged and this timing allows for better selectivity, as the herbicide can be targeted to the soil where weed seeds are present, minimizing contact with emerging crop plants, which reduces the risk of crop injury and enhances overall crop safety (Cioni and Maines 2010; Zimdahl 2018). Several pre-emergence herbicides have gained prominence in agricultural practices, and these include Group 14 herbicides (such as sulfentrazone and flumioxazin) and Group 15 herbicides (like acetochlor, metolachlor, and S-metolachlor), which effectively control both broadleaf weeds and grasses in crops of corn, soybeans, cotton, and peanuts (Umphres et al. 2018; Brabham et al. 2019; Rangani et al. 2021; Wang et al. 2021). In addition, Group 5 herbicides (such as metribuzin and flumioxazin) are employed for broad-spectrum weed control in crops like potatoes, soybeans, and peas (Ali et al. 2020; Hutchinson 2020) whereas Group 3 herbicides (like pendimethalin and trifluralin) exhibit selectivity in controlling grassy weeds and are widely used in various crops, including corn, wheat, and several vegetables (Chhokar et al. 2012; Parween et al. 2016). Therefore, the pre-emergence herbicides of Group 3, Group 5, Group 14, and Group 15 have become integral components of weed management in different crop types, ensuring efficient control of both broadleaf weeds and grasses.

III. USE OF GENETICALLY MODIFIED HERBICIDE-RESISTANT CROPS

The phenomenon of adopting genetically modified (GM) herbicide-resistant crops has emerged as a prominent trend in herbicide usage within the agricultural sector over the past few decades (Meftaul et al. 2020). These crops are genetically engineered to tolerate specific herbicides, allowing farmers to control weeds more effectively while minimizing damage to the cultivated crops (Duke and Powles 2008; Owen et al. 2015). Notably, glyphosate-resistant crops such as soybeans, corn, cotton, and canola have gained widespread acceptance among farmers globally (Duke and Powles 2008). The introduction of glyphosate-resistant crops has led to increased reliance on glyphosate-based herbicides, like Monsanto's RoundupR (Belz and Duke 2014). The glyphosate-resistant crops have provided farmers with more flexibility and convenience in weed management, resulting in enhanced crop yields and reduced labor costs. Apart from glyphosate resistance, crops with resistance to other herbicides have also been developed and commercialized.

For example, crops engineered to tolerate herbicides like glufosinate, 2,4-D, and dicamba have gained adoption in various regions (Shaner 2014). These herbicide-resistant crops provide farmers with additional options for weed control and help manage herbicide resistance by rotating the use of different herbicides (Gaines et al. 2010). The adoption of GM herbicide-resistant crops has provided several benefits to farmers, including improved weed control, increased crop yields, and reduced tillage (Powles and Yu 2010).

However, there are concerns related to herbicide-resistant

IV. CONCLUSIONS AND FUTURE PERSPECTIVES

The application of herbicides is crucial in modern agriculture worldwide. However, improper use of these chemicals can threaten human and environmental health. In fact, excessive and repeated use of herbicides over an extended period can lead to the development of resistance in weedspecies toward specific weedicides. Furthermore, the offsite migration of herbicides through runoff and leaching can contaminate surface and groundwater, thereby adversely affecting aquatic organisms. Recent trends indicate a shift towards more precise and targeted formulations of herbicides, increased utilization of systemic and pre-emergence herbicides, and decreased overall herbicide usage. However, global agriculture encounters numerous challenges due to the adverse environmental impacts stemming from herbicide contamination, both at application site and offsite. Due to growing concerns, it is crucial to innovate herbicides with better selectivity or develop bio-based alternatives. Enzyme inhibitors and receptor-based herbicides can offer precise weed control and reduce ecological implications. Rapidlydegrading herbicides or those binding firmly to soil particles are needed to prevent groundwater or surface water contamination.

Sustainable weed management practices, like using remote sensing, drones, and machine learning, can enable real-time weed detection and targeted herbicide application. Public awareness and constructive dialogue about herbicide safety should be prioritized through educational campaigns targeting consumers, farmers, and stakeholders.

REFERENCES

1. Yin, Y., Liu, S., Yang, Y., Gong, D., Liu, M., Liu, G., Wu, P., Xu, Q., Yu, C., & Zeng, G. (2023). Polyethyleneimine–polyvinylchloride-based crosslinked membranes for use in PEM water electrolysis operating above 100 °C. International Journal of Hydrogen Energy, 48(1), 24–34.
2. Sharma, P. P., Gupta, H., & Kulshrestha, V. (2020). Phosphorylated hybrid silica–sulfonated polyethersulfone composite proton-exchange membranes: Magnetic resonance investigation for enhanced proton-exchange dynamics. International Journal of Hydrogen Energy, 45(34), 16955–16964.
3. Siracusano, S., Baglio, V., Nicotera, I., Mazzapioda, L., Aricò, A. S., Panero, S., & Navarra, M. A. (2017). Sulfated titania as additive in Nafion membranes for water electrolysis applications. International Journal of Hydrogen Energy, 42(46), 27851–27858.
4. da Costa, E. P., Coelho, S. E., de Oliveira, A. H., Araújo, R. M., Cavalcanti, L. N., Domingos, J. B., & Menezes, F. G. (2018). Multicomponent synthesis of substituted 3-styryl-1H-quinoxalin-2-ones in an aqueous medium. Tetrahedron Letters, 59(44), 3961–3964.
5. Reddy, M. S., Chowhan, L. R., Kumar, N. S., Ramesh, P., & Mukkamala, S. B. (2018). An expedient regio- and diastereoselective synthesis of novel spiropyrrolidinylindenoquinoxalines via 1,3-dipolar cycloaddition reaction. Tetrahedron Letters, 59(14), 1366–1371.
6. Farooq, S., & Ngaini, Z. (2021). Chalcone-derived benzoheterodiazepines for medicinal applications: A two-pot and one-pot synthetic approach. Journal of Heterocyclic Chemistry, 58(10), 1914–1928.
7. Thakur, A., Verma, M., Setia, P., Bharti, R., Sharma, R., Sharma, A., Negi, N. P., Anand, V., & Bansal, R. (2023). DFT analysis and in vitro studies of isoxazole derivatives as potent antioxidant and antibacterial agents synthesized via one-pot methodology. Research on Chemical Intermediates, 49(3), 859–883.
8. Teli, S., Teli, P., Soni, S., Sahiba, N., & Agarwal, S. (2023). Synthetic aspects of 1,4- and 1,5-benzodiazepines using o-phenylenediamine: A study of the past quinquennial. RSC Advances, 13(6), 3694–3714.
9. Thakral, A., Verma, M., Thakur, A., Bharti, R., & Sharma, R. (2024). Comprehensive review on one-pot green synthesis of pyran and chromene fused benzo[α]phenazines. Polycyclic Aromatic Compounds, 44(3), 1697–1721.
10. Thakur, A., Verma, M., Setia, P., Bharti, R., Sharma, R., Sharma, A., Negi, N. P., Anand, V., & Bansal, R. (2023). DFT analysis and in vitro studies of isoxazole derivatives as potent antioxidant and antibacterial agents synthesized via one-pot methodology. Research on Chemical Intermediates, 49(3), 859–883. [Duplicate of Ref. 7]
11. Indalkar, K. S., Patil, M. S., & Chaturbhuj, G. U. (2017). An efficient, environmentally benign, and solvent-free protocol for the synthesis of 4-substituted 1,5-benzodiazepines catalyzed by reusable sulfated polyborate. Tetrahedron Letters, 58(48), 4496–4502.
12. da Costa, E. P., Coelho, S. E., de Oliveira, A. H., Araújo, R. M., Cavalcanti, L. N., Domingos, J. B., & Menezes, F. G. (2018). Multicomponent synthesis of substituted 3-styryl-1H-quinoxalin-2-ones in an aqueous medium. Tetrahedron Letters, 59(44), 3961–3964. [Duplicate of Ref. 4]
13. Reddy, M. S., Chowhan, L. R., Kumar, N. S., Ramesh, P., & Mukkamala, S. B. (2018). An expedient regio- and diastereoselective synthesis of novel spiropyrrolidinylindenoquinoxalines via 1,3-dipolar cycloaddition reaction. Tetrahedron Letters, 59(14), 1366–1371. [Duplicate of Ref. 5]
14. Shaabani, A., Hooshmand, S. E., Nazeri, M. T., Afshari, R., & Ghasemi, S. (2016). Deep eutectic solvent as a highly efficient reaction medium for the one-pot synthesis of benzo-fused seven-membered heterocycles. Tetrahedron Letters, 57(33), 3727–3730.
15. Zhong, R., Lindhorst, A. C., Groche, F. J., & Kühn, F. E. (2017). Immobilization of N-heterocyclic carbene compounds: A synthetic perspective. Chemical Reviews, 117(3), 1970–2058.
16. Sharghi, H., Shiri, P., & Aberi, M. (2017). Five-membered N-heterocycles synthesis catalyzed by nano-silica-supported copper(II)–2-imino-1,2-diphenylethan-1-ol complex. Catalysis Letters, 147, 2844–2862.
17. Salehpour, M., Azizian, J., & Kefayati, H. (2017). Clean synthesis of novel spiro[indene-2,2′-[1,3,5]-oxathiazine]-1,3-diones in water. Chinese Chemical Letters, 28(5), 1079–1082.