RJC

RASĀYAN *J. Chem.*
Vol. 15 | No. 4 |2596-2604| October - December | 2022
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

$NbCl_5$+$AgClO_4$ AS A VERSATILE COMBINED CATALYST SYSTEM FOR AN ACCELERATED SYNTHESIS OF 1, 4-DIHYDROPYRIDINE SCAFFOLDS

Manisha Bora[1], Kailas Kadam[2], Punam Wani[3], and Narendra Kamble[4,✉]
[1]Department of Chemistry, B.J.S.'s ASC College, Wagholi, Pune, Maharashtra, India
[2]Department of Chemistry, P.V.P. College, Pravaranagar,Ahmednagar, Maharashtra, India
[3]Department of Physics, P.D.E.A.'s Prof. Ramkrishna More College, Akurdi, Pune, Maharashtra, India
[4]Department of Chemistry, P.D.E.A.'s Waghire College, Saswad, Pune, Maharashtra, India
✉Corresponding Author: narendra1499@gmail.com

ABSTRACT

Herein presented work describes the catalytic potential of $NbCl_5$+$AgClO_4$ as a combined and convenient catalyst system for a straightforward, safe, quick, and single-pot synthesis of 1, 4-dihydropyridine (DHP) scaffolds. It was investigated that a small amount of $NbCl_5$+$AgClO_4$ is sufficient and potential enough to bring out the solvent-free synthesis of 1, 4-dihydropyridine scaffolds from a three-components, the cyclic reaction between substituted aldehyde(s), ethyl-3-oxobutanoate, and ammonium ethanoate. It is noteworthy to mention that good to excellent yields of DHPs were achieved by developing an environmentally compatible, sustainable, mild, and simple synthetic protocol. A range of differently substituted aldehydes was observed to undergo herein developed catalytic protocol smoothly to offer good yields of DHPs in 3 to 5 h at room temperature. Representative DHPs are characterized by adequate analytical techniques such as FTIR, ^{1}HNMR, ^{13}CNMR, and mass spectrometric techniques.

Keywords: Solid-State, Combined Catalyst, One-Pot Synthesis, DHPs

RASĀYAN*J. Chem.*, Vol. 15, No.4, 2022

INTRODUCTION

It is recognized that most of the heterocyclic molecules like DHPs are analogous to vital drug categories.[1]Substituted DHPs exhibit numerous remedial solicitations that comprise anti-aggregator, and anti-ischemic agents in the management of Alzheimer's disease, as well as a chemical sensitizer in cancer chemotherapy.[2-5] Some of these instances illustrate the notable perspective of DHPs as a precursor or source of valued drug contenders. These 1, 4-dihydropyridines are then oxidized to pyridines.[6]The conventional process of the preparation of 1, 4-DHPs is a single versus multi-constituent response of ammonium ethanoate, aldehyde with ethyl-3-oxobutanoate in the presence of either some acid or by heating in alcohol.[7]Nevertheless, the yields of 1, 4-DHPs obtained by the conventional processes are commonly very low. The well-known Hantzsch synthesis process for 1, 4-DHP derivatives includes severe reaction circumstances, longer synthesis durations, and stumpy product yields.[8-12]Many improved synthetic approaches have been reported in the literature, but most of them have a number of drawbacks, including low yields, longer reaction times, the use of toxic catalysts, the need for specialized equipment, and the use of large amounts of harmful solvents.[13-14] Consequently, the development of new alternative routes, which avoid the usage of toxic, expensive catalysts, and hazardous solvent to construct DHP derivatives, is of great commercial interest. To prepare substituted DHP derivatives, traditional heating, solar thermal energy, ionic liquid, grinding, p-TSA, L-proline, nanoparticles, and other advanced methods have been used.[15-23]Despite the fact that many of the developments have distinct advantages, their application is limited due to the use of elevated temperatures, luxurious metal salts, ecologically hazardous catalysts, punitive reaction requirements, extended reaction epochs, and huge quantities of organic solvent systems. Recently, robust Lewis acids like $NbCl_5$ have been employed as an innovative catalytic agent in man-made chemistry due to their permanence, reduced moisture-absorbing character, and stress-free handling compared to reported Lewis acids. Several organic reactions catalyzed by $NbCl_5$have been formerly testified.[24-29] Keeping in mind the importance of solid-state synthetic organic

http://doi.org/10.31788/RJC.2022.1548086

chemistry and in the extension of our previous research work in multi-component synthesis, here we describe a new, eco-friendly, mild, facile, and efficient solvent-free approach for the synthesis of 1, 4-DHPs obtained by using various aldehydes, ammonium ethanoate and, ethyl-3-oxobutanoate with $NbCl_5$ and $AgClO_4$ combined catalyst system. All the synthesized substituted DHP molecules were characterized by various techniques like FTIR, NMR, and mass spectrometry. The present protocol gives excellent yields in a short reaction time with great purity.

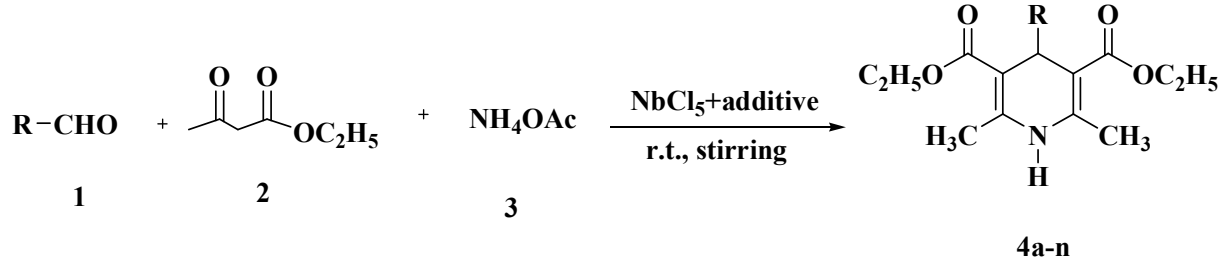
EXPERIMENTAL

Materials

Ethyl acetate, ammonium ethanoate, aldehydes, $NbCl_5$, and $AgClO_4$ were obtained from SD Fine chemicals, India. All-inclusive chemicals procured (AR grade) cast-off as obtained without any refinement.

Multicomponent Preparation of 1, 4-DHPs

A combination of aldehydes, ammonium ethanoate, and ethyl-3-oxobutanoate in 1:3:2 molar ratios was taken in a single flask and agitated for about three to five minutes at room temperature. Then, to the above reaction mixture, $NbCl_5$ and $AgClO_4$, a combined catalyst system (5 mmol) was added and stirred more in a single pot for the suitable interval (scheme-I). The development of the process was examined using TLC every 10-minute intervals. After the execution of the reaction, the blend was transferred to 20 g of crushed ice with continuous stirring. The precipitate obtained was isolated by vacuum filtration and then air-dried. For oily products, the reaction blend was added to 50 mL of ice-chilled water and then extracted by using ethyl acetate. All collective organic layers were parched over anhydrous Na_2SO_4 before the isolation of the product. The physical constants of all the derivatives were recorded.



Scheme-I

Characterization

Altogether chemicals obtained were analytical grade and cast-off, with no additional refinement. The IR spectra were recorded on the SHIMADZU FT-IR 8400 by means ofKBr pellets. The ^{1}H-NMR was verified in $CDCl_3$ on BRUCKER (300 MHz) and the LC-mass spectra were recorded on the SHIMADZU MODEL-8045.

RESULTS AND DISCUSSION

Optimization of Reaction Controls

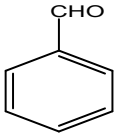
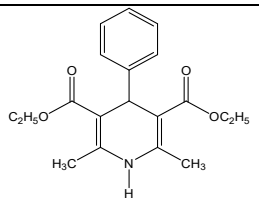
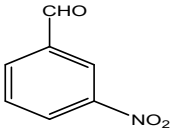
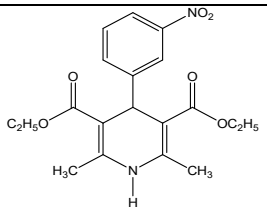
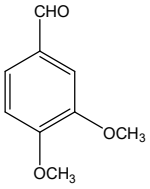
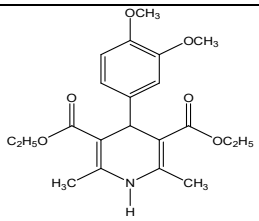
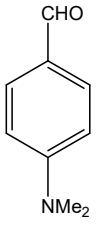
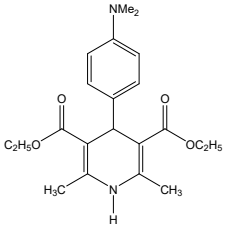
For catalytic evaluation of $NbCl_5$ and $AgClO_4$ as Lewis acids, control reaction of benzaldehyde, ammonium ethanoate, and ethyl-3-oxobutanoate under several reaction situations (Table-1). The reaction proceeding without a catalyst produces less quantity of product even after 20 hours of long duration. (Table-1). The sub-standard product yields were gained with various polar and non-polar solvents (Table-1, 2-5) than the solvent-free reaction carried in the solid state.The optimization of the amount of $NbCl_5$ and $AgClO_4$ catalyst system at ambient temperature in solid-state conditions for control reaction (Table-1, entries 6-11) was carried out. It was perceived that the consumption of just 5mmol of combined catalyst was adequate for the accomplishment in 3 to 5 hours with a 90% yield of the resultant product (entry-9). It was critical to note that increasing the amount of catalyst did not increase product yields or reaction duration (Table-1, entries 10-11). It was also perceived that with less than a catalyst concentration of 5 mmol, the reaction was incomplete resulting in a poor amount of the product (Table-1, entries 6-8).The results offered in Table-2 specify the opportunity and overview of the present protocol, which is efficient for an extensive series of substrates. Furthermore, aromatic aldehydes bearing either electron-releasing or extracting substituents reacted intensely under the reaction protocol to produce the corresponding 4-

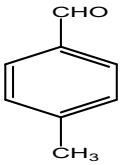
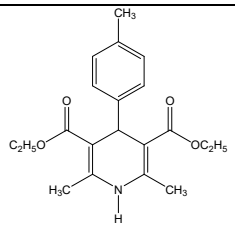
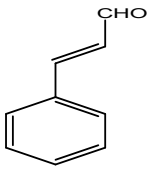
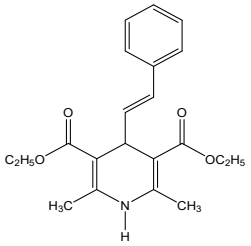
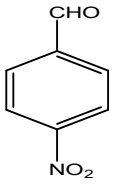
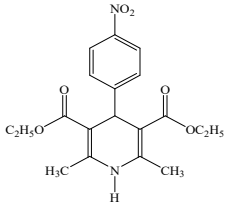
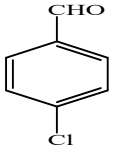
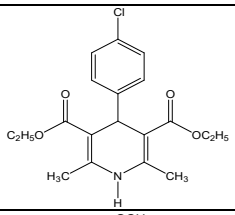
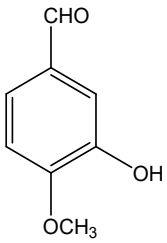
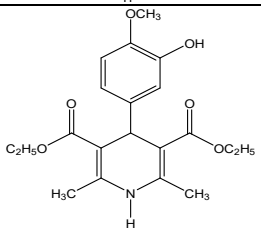
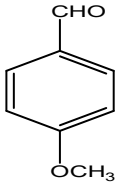
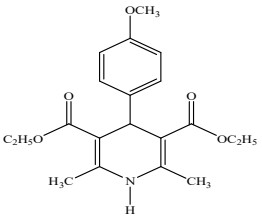
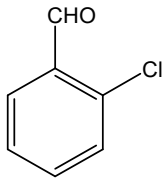
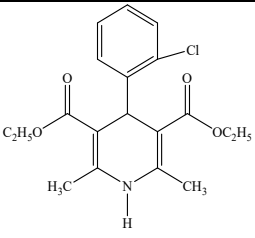
substituted 1, 4-dihydropyridine derivatives in decent to great yields with extraordinary purity. The vital significance of the present approach is the capability to allow deviations in all three constituents as well as the persistence of a variety of functional assemblies. In comparison to earlier reported approaches, which are only applied to aromatic aldehydes, the currently reported process is superior and is operative even with aliphatic aldehydes.

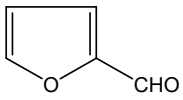
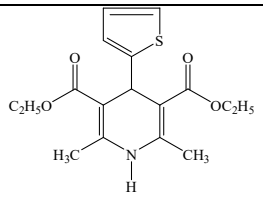
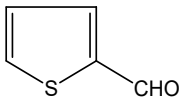
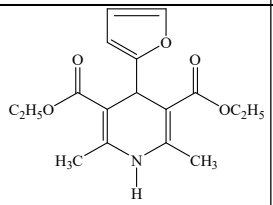
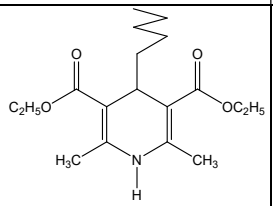
Table-1: Reaction Optimization Parameters

S. No.	Solvent	Catalyst (mmol)	Time (Hrs.)	Yield (%)
1	solid -state: without catalyst	---	20	25
2	CH_2Cl_2	5	15	55
3	THF	5	12	69
4	CH_3CN	5	12	61
5	$CHCl_3$	5	15	64
6	solid -state	2	10	51
7	solid -state	1	10	63
8	solid -state	3.5	7	81
9	solid -state	5	4	90
10	solid -state	6	4	90
11	solid -state	7	4	90

Table-2: Synthesis of 1, 4-dihydropyridine Derivatives

Entry	Reactant aldehyde	Product	Time (hrs)	Yield (%)	Physical state	MP (°C)
4a			4.35	90	Solid	157-158°C
4b			5.20	96	Solid	150-151°C
4c			4.00	89	Solid	118-120°C
4d			4.15	88	Solid	102-104°C

4e			4.00	93	Solid	140-142°C
4f			4.30	88	Solid	128-130°C
4g			5.00	92	Solid	107-108°C
4h			4.15	94	Solid	128-130°C
4i			4.15	90	Solid	139-140°C
4j			3.45	96	Solid	188-190°C
4k			4.30	89	Solid	157-158°C

4l			6.00	88		158-160ºC
4m			5.30	89	Solid	136-138ºC
4n			5.30	88	Oily syrup	--

Spectral Analysis

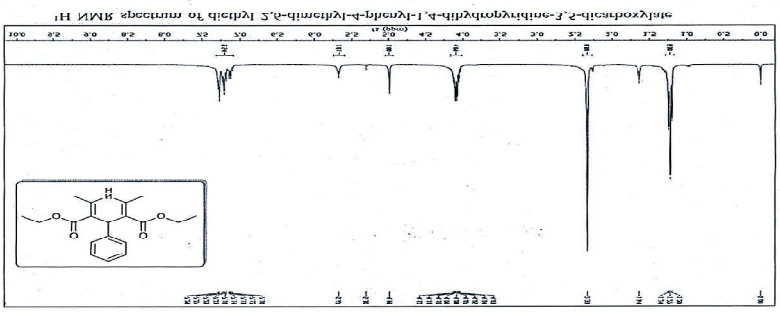


Fig.-1:[1]HNMR of 4a

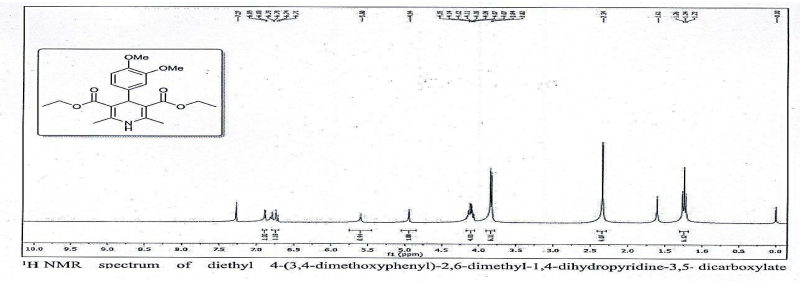


Fig.-2: [1]HNMR of 4c

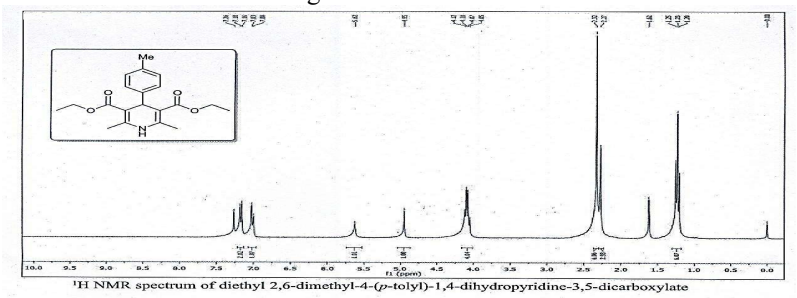
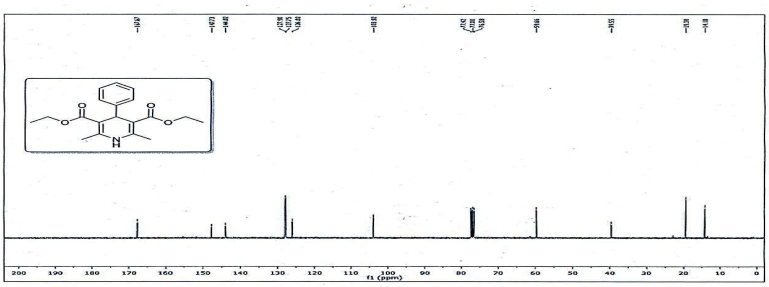
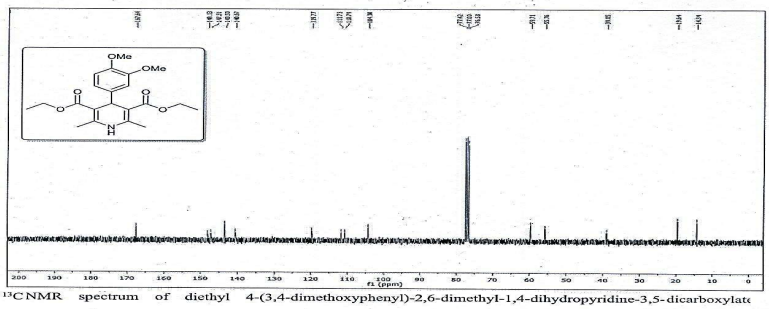


Fig.-3: [1]HNMR of 4e



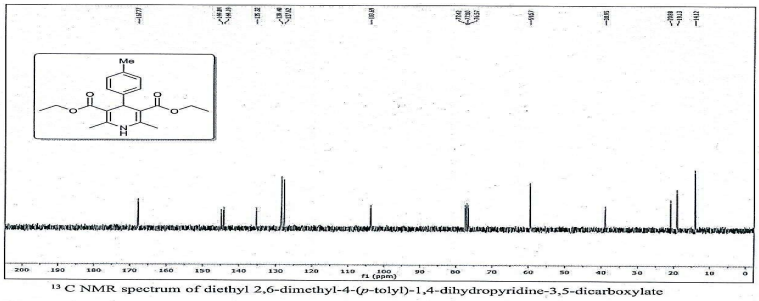
^{13}C NMR spectrum of diethyl 2,6-dimethyl-4-phenyl-1,4-dihydropyridine-3,5-dicarboxylate

Fig.-4:^{13}CNMR of 4a



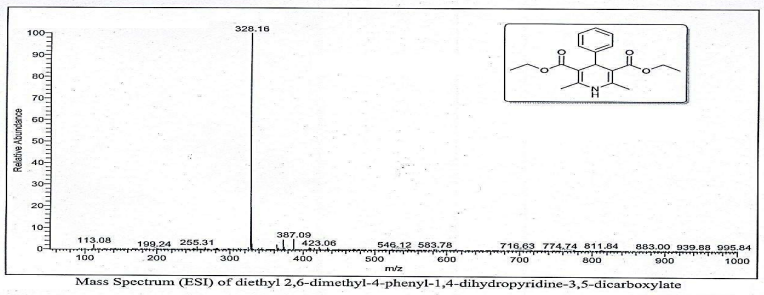
^{13}C NMR spectrum of diethyl 4-(3,4-dimethoxyphenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate

Fig.-5:^{13}CNMR of 4c



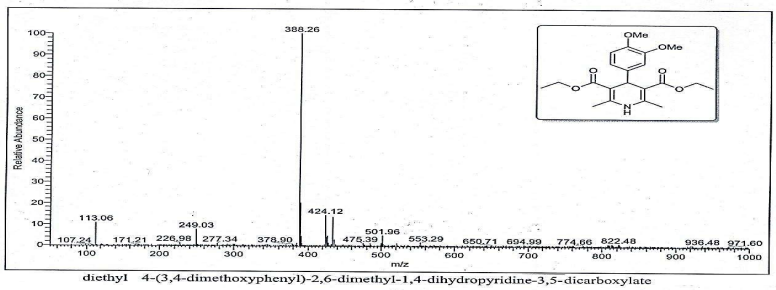
^{13}C NMR spectrum of diethyl 2,6-dimethyl-4-(*p*-tolyl)-1,4-dihydropyridine-3,5-dicarboxylate

Fig.-6:^{13}CNMR of 4e



Mass Spectrum (ESI) of diethyl 2,6-dimethyl-4-phenyl-1,4-dihydropyridine-3,5-dicarboxylate

Fig.-7: LCMS of 4a



diethyl 4-(3,4-dimethoxyphenyl)-2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate

Fig.-8: LCMS of 4c

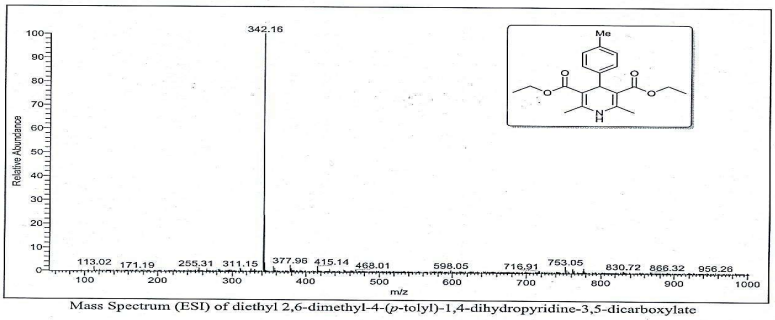


Fig.-9: LCMS of 4e

Characterization

The products obtained were recognized by matching with the physical constants, FT-IR, 1HNMR, and Mass (LC-MS).

Spectral Analysis

4a: FTIR (KBr): 3341, 2976, 1688, 1485 cm^{-1}; ^{1}HNMR: δ ppm = 1.26 (6H, t, 7.38Hz, $2CH_3$), 2.28 (6H,s, $2CH_3$), 4.10 (4H, *q,* 7.4 Hz,$2OCH_2$), 4.90 (1H,s, CH), 5.62 (NH), 6.98-7.1 (5H,m, Ar); MS(*m/e*)= 330 (MH^+); Obtained: C, 69.24; H, 7.07; N, 4.23.

4b: FTIR (KBr): 3328,2986,1685,1527 cm^{-1}; ^{1}HNMR: δ ppm = 1.24 (6H, t*,* 7.8 Hz, $2CH_3$), 2,32 (6H,s, $2CH_3$), 4,20 (4H, q, 7.8 Hz, $2OCH_2$), 4.95 (1H,s, CH), 5.68 (NH), 7.15-7.30 (1H,m, Ar), 7.50 (2H,m, Ar), 7.80 (1H,d, 8.6 Hz, Ar); MS(*m/e*) = 375 (MH^+).; Obtained: C, 60.92; H, 5.90; N, 7.45.

4c: FTIR (KBr): 3330,2976,1686,1530 cm^{-1}; ^{1}HNMR: δ ppm= 1.23 (6H,t, 7.8 Hz, $2CH_3$), 2.28 (6H,s, $2CH_3$), 4.02 (3H,s, OCH_3), 4.10 (3H,s, OCH_3), 4.23 (4H,q,7.8 Hz, $2OCH_2$), 4.90 (1H,s, CH), 5.70 (NH), 7.70 (1H,s, Ar) 7.81 (2H,d, 8.3 Hz, Ar); MS(*m/e*) = 390 (MH^+).; Obtained: C, 64.74; H, 6.96; N,3.56.

4d: FTIR (KBr):3349, 2969, 1617, 1570, 1302 cm^{-1}; ^{1}HNMR: δ ppm = 1.11 (6H, t, 7.4 Hz, $2CH_3$), 2.28 (6H,s, $2CH_3$), 2.99 (6H,s, NCH_3), 4.09 (4H, q, 7.4 Hz, $2OCH_2$), 4.98 (1H,s, CH), 5.78 (NH), 7.49 (2H,d, 8.1Hz, Ar), 8.06 (2H, d*,* 8.3 Hz, Ar); MS(*m/e*)= 373 (MH^+); Obtained: C, 67.69; H, 7.59; N, 7.49.

4e: FTIR (KBr): 3432, 3025, 1689, 1468 cm^{-1}; ^{1}HNMR: δ ppm = 1.22 (6H, t, 7.1 Hz, $2CH_3$), 2.26 (3H,s, CH_3), 2.30 (6H,s, $2CH_3$), 4.04 (4H,q, 7.2 Hz, $2OCH_2$), 4.91 (1H,s, CH), 5.65(NH), 7.13 (2H,d, 8.1 Hz, Ar), 7.59 (2H, d,8.0 Hz, Ar); MS: *m/e* = 344 (MH^+).; Obtained: C, 69.91; H,7.37; N,4.03.

4f: FTIR (KBr): 3347, 2976, 1687,1480 cm^{-1}; ^{1}HNMR: δ ppm = 1.20 (6H, t, 7.5 Hz, $2CH_3$), 2,32 (6H,s, $2CH_3$), 4.05 (4H,q, 7.5 Hz, $2OCH_2$), 4.90 (1H,s, CH), 5.60 (NH), 6.11 (1H,d, 6.0 Hz, sp^2CH) 6.43 (1H, *d,*15.2 Hz, sp^2CH), 7.13-7.41 (5H,m, Ar); MS(*m/e*)= 356 (MH^+); Obtained: C, 64.74; H, 7.02; N, 3.62.

4g: FTIR (KBr): 3320, 2947, 1696,1485 cm^{-1}; ^{1}HNMR: δ ppm = 1.17 (6H, t,7.2 Hz, $2CH_3$), 2.32 (6H,s, $2CH_3$), 4.07 (4H,q,7.2 Hz, $2OCH_2$), 4.98 (1H,s, CH), 5.67 (NH), 7.42 (2H,d, 8.3Hz, Ar) 8.03 (2H, d, 8.3Hz, Ar); MS(*m/e*)= 375 (MH^+); calculated for [$C_{19}H_{22}N_2O_6$] C, 60.94; H, 5.92; N, 7.48; Obtained: C, 60.92; H, 5.90; N, 7.45.

4h:FTIR (KBr): 3354, 2952, 1647,1333 cm^{-1}; ^{1}HNMR: δ ppm = 1.15 (6H, t, 7.8 Hz, $2CH_3$), 2,24 (6H,s, $2CH_3$), 4.03 (4H,q,7.5 Hz ,$2OCH_2$), 4.80 (1H,s, CH), 5.76 (NH), 7.08 (2H, d, 8.1 Hz, Ar) 7.71 (2H, d, 8.1 Hz, Ar); MS(*m/e*)= 364 (MH^+).; Obtained: C, 62.70; H, 6.10;N, 3.82.

4i:FTIR (KBr): 3353, 2982, 1681,1505,1371 cm^{-1}; ^{1}HNMR): δ ppm = 1.20 (6H,t, 7.0 Hz, $2CH_3$), 2,31 (6H,s, $2CH_3$), 3.82 (3H,s, OCH_3), 4.01 (4H,q,7.0 Hz, $2OCH_2$), 4.96 (1H,s, CH), 5.30 (1H,s, OH), 5.70(

NH), 7.40-7.41 (2H,m, Ar), 7.75 (1H,d,8.2Hz, Ar); MS(*m/e*) = 376 (MH^+).; Obtained: C, 63.96; H, 6.73; N, 3.71.

4j:FTIR (KBr): 3335, 2976, 1693, 1498 cm^{-1}; ^{1}HNMR: δ ppm = 1.18 (6H,t,7.3Hz, $2CH_3$), 2.30 (6H,s, $2CH_3$), 3.80 (3H, s, OCH_3), 4.10 (4H,q, 7.3Hz, $2OCH_2$), 4.80 (1H,s, CH), 5.76 (NH), 7.01 (2H, s,8.1Hz, Ar), 7.20 (2H,d,8.1Hz, Ar); MS(*m/e*) = 360 (MH^+).; Obtained: C, 66.81; H, 7.04; N, 3.87.

4k: FTIR (KBr): 3347, 2982, 1681,1498,1377 cm^{-1}; ^{1}HNMR: δ ppm = 1.20 (6H,t,7.8 Hz, $2CH_3$), 2.34 (6H,s, $2CH_3$), 4.10 (4H,q, 7.4Hz, $2OCH_2$), 5.01 (1H,s, CH), 5.60 (NH), 7.30-7.92 (4H,m,Ar); MS(*m/e*)= 364 (MH^+).; Obtained: C, 62.00; H, 6.12; N, 3.81.

4l: FTIR (KBr): 3349, 2992, 1695,1490,772 cm^{-1}; ^{1}HNMR: δ ppm = 1.30 (6H,t, 8.4 Hz, $2CH_3$), 2.21 (6H, s,$2CH_3$), 4.16 (4H, q,8.4Hz, $2OCH_2$),5.22 (1H,s, CH), 5.94 (NH), 6.78-6.98 (3H,m, Ar); MS(*m/e*)= 336 (MH^+).; Obtained: C, 60.85; H, 6.29; N, 4.17.01;S, 9.53.

4m: FTIR (KBr): 3346, 2993, 1698, 1493 cm^{-1}; ^{1}HNMR: δ ppm = 1.20 (6H,t, 8.6 Hz, $2CH_3$), 2.40 (6H, s, $2CH_3$), 4.20 (4H,q, 8.2 Hz, $2OCH_2$), 5.32 (1H,s, CH),5.96 (NH), 7.01 -7.23 (3H,m, Ar); MS(*m/e*) = 320 (MH^+).; Obtained: C, 63.90; H, 6.65; N, 4.35.

4n: FTIR (KBr): 3350, 2995, 1770, 1686, 1245 cm^{-1}; ^{1}HNMR: δ ppm = 0.86 (6H,t, 8.3 Hz, $2CH_3$), 1.10-1.49 (11H,m), 2.20 (6H,s, $2CH_3$), 3.87 (1H, t,8.3 Hz, CH),4.16 (4H,q,7.6 Hz, $2OCH_2$), 5.76 (NH); MS(*m/e*) = 324 (MH^+).; Obtained: C, 66.81; H, 9.07; N, 4.30.

CONCLUSION

A facile, advanced, appropriate, and green route for the preparation of 1, 4-dihydropyridines has been developed.The multi-component approach by using various aldehydes, ethyl-3-oxobutanoate, and ammonium ethanoate with $NbCl_5$ and $AgClO_4$ as a combined catalyst system was developed successfully. The important features of the reported protocol are stress-free work-up, easy isolation of products by simple filtration, a cleaner reaction profile, and an accessible process towards the synthesis of 1, 4-DHPs of biotic importance.

ACKNOWLEDGEMENT

We are thankful to S P Pune University for providing instrumental facilities at CIF.

REFERENCES

1. D. Mauzeral and F. H. Westhiemer, *Journal of American Chemical Society,* **77(8)**, 2261(1955), http://doi.org/10.1021/ja01613a070
2. V. Klusa, *Drugs of Future,* **20(9)**, 135 (1995), http://doi.org/10.1358/dof.1995.020.02.284117
3. R. G. Bretzel, C. C. Bollen, E. Maeser and K. F. Federlin, *Drugs of Future,* **41(2)**, 479(1992), https://doi.org/10.1038/ki.1992.66
4. R. G. Bretzel, C. C. Bollen, E. Maeser, K. F. Federlin, *American Journal of Kidney Diseases*, **21(6)**, 53(1993), http://doi.org/10.1016/0272-6386(93)70125-i
5. R. Boer, U. Gekeler, *Biochemical and Biophysical Research Communications,* **206(1)**, 119(1995), http://doi.org/10.1006/bbrc.1995.1017
6. T. Itoh, K. Nagata, Y. Matsuya, M. Miyazaki, A. Ohsawa, *Journal of Organic Chemistry,* **62(11)**, 3582(1997), http://doi.org/10.1021/jo962101e
7. A. Hantzsch, *LiebigsAnnalen der Chemie,***(215)1**, 1(1882), http://doi.org/10.1002/jlac.18822150102
8. I. R. Alajar, J. J. Vaquero, J. L. Garcia Navio, J. Alvarez Builla, *Synlett,* **(4)**, 297(1992), http://doi.org/10.1055/s-1992-21345.
9. Y. Watanabe, K. Shiota, T. Hoshiko, S. Ozaki, *Synthesis,* **(9)**, 761(1983), http://doi.org/10.1055/s-1983-30505
10. G. Sabitha, G. S. Reddy, C. S. Reddy, J. S. Yadav, *Tetrahedron Letters,* **44(21)**, 4129(2003), http://doi.org/10.1016/S0040-4039(03)00813-X
11. G. V. M. Sharma, K. L. Reddy, P. S. Lakshmi, P. R. Krishna, *Synthesis,* **01,** 55(2006),

http://doi.org/10.1055/s-2005-921744
12. M. Maheswara, V. Siddaiah, Y. K. Rao, Y. M. Tzeng, C. Sridhar, *Journal of Molecular Catalysis A: Chemical*, **260(1-2)**, 179(2006), http://doi.org/10.1016/j.molcata.2006.07.024
13. L. Öhberg, J. Westman, *Synlett,* **8**, 1296(2001), http://doi.org/10.1055/s-2001-16043
14. J. G. Breitenbucher, G. Figliozzi, *Tetrahedron Letters,* **41(22)**, 4311(2000), http://doi.org/10.1016/S0040-4039(00)00660-2
15. K. M. Love, B. Snader, *Journal of Organic Chemistry,* **30(6)**, 1914(1965), http://doi.org/10.1021/jo01017a048
16. J. B. Sainani, A. C. Shah, V. P. Arya, *ChemInform*, **25**, 40(2010), http://doi.org/10.1002/chin.199440153
17. M. Sufirez, E. Ochoa, Y. Verdecia, B. Verdecia, L. Moran, N. Martin, M. Quinteiro, C. Seoane, J. L. Soto, H. Novoa, N. Blaton, O. M. Peters, *Tetrahedron*, **55(3)**, 875(1999), http://doi.org/10.1016/S0040-4020(98)01078-3
18. R. A. Mekheimer, A. A. Hameed, K. U. Sadek, *Green Chemistry,***10(5)**, 592(2008), http://doi.org/10.1039/B715126H
19. S. J. Ji, Z. Q. Jiang, J. Lu, T.P. Loa, *Synlett*, **05**, 831(2004), http://doi.org/10.1055/s-2004-820035
20. L. M. Wang, J. Sheng, L. Zhang, J. W. Han, Z. Y. Fan, H. Tian, C. T. Qian, *Tetrahedron*,**61(6),** 1539(2005), http://doi.org/10.1016/j.tet.2004.11.079
21. S. Kumar, P. Sharma, K. K. Kapoor, M. S. Hundal, *Tetrahedron*, **64(3)**, 536(2008), http://doi.org/10.1016/j.tet.2007.11.008
22. S. R. Cherkupally, R. Mekalan, *Chemical and Pharmaceutical Bulletin,* **56(7)**, 1002(2008), http://doi.org/10.1248/cpb.56.1002
23. C. G. Evans, J. E. Gestwicki, *Organic Letters,* **11(14)**, 2957(2009), http://doi.org/10.1021/ol901114f
24. S. B. Sapkal, K. F. Shelke, B. B. Shingate, M. S. Shingare, *Tetrahedron Letters,***50(15)**, 1754(2009), http://doi.org/10.1016/j.tetlet.2009.01.140
25. K. R. Kadam, N. R. Kamble, V. T. Kamble, *Rasayan Journal of Chemistry*, **13(2)**, 854(2020), http://dx.doi.org/10.31788/RJC.2020.1325728
26. N. R. Kamble, H. R. Pawar, V. T. Kamble, *Asian Journal of Chemistry*, **32(2)**, 317(2020), http://doi.org/10.14233/ajchem.2020.22419
27. N. R. Kamble, V. T. Kamble, *Asian Journal of Chemistry*, **31(6)**, 1357(2019), http://doi.org/10.14233/ajchem.2019.21986
28. H. R. Pawar, N. R. Kamble, V. T. Kamble, *Rasayan Journal of Chemistry*, **12(4)**, 1997(2019), http://doi.org/10.31788/RJC.2019.1245381
29. A. H Cahyana, A. R. Liandi, Y. Safitri, R. Yunarti, *Rasayan Journal of Chemistry,* **13(3),** 1491(2020), http://dx.doi.org/10.31788/ RJC.2020.1335700

[RJC-8086/2022]