Tetrahedron Letters 50 (2009) 6977–6980

Contents lists available at ScienceDirect

Tetrahedron Letters

journal homepage: www.elsevier.com/locate/tetlet

Acyclic ketene aminal phosphates derived from *N,N*-diprotected acetamides: stability and cross-couplings

Alessandro B. C. Simas *, Daniel L. de Sales, Karla C. Pais

Núcleo de Pesquisas de Produtos Naturais (NPPN), Universidade Federal do Rio de Janeiro, Laboratório Roderick A. Barnes, Ilha do, Fundão, Prédio do CCS, bloco H, Av. Carlos Chagas Filho, 373, Rio de Janeiro, RJ 21941-902, Brazil

ARTICLE INFO

Article history:
Received 8 September 2009
Revised 23 September 2009
Accepted 25 September 2009
Available online 1 October 2009

Keywords:
Stille reaction
Suzuki reaction
Catalysis
Enyne
Diene

ABSTRACT

The synthesis of a stable ketene aminal phosphate (α-phosphoryloxy enecarbamate) derived from *N,N*-diprotected acetamide, bearing two different removable protecting groups, is disclosed. This synthetic intermediate underwent successful palladium-catalyzed cross-coupling reactions to afford functionalized enynes and dienes.

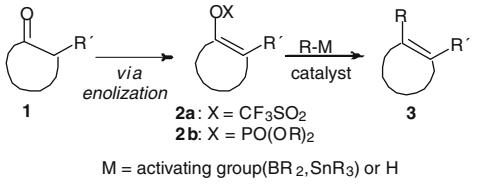
© 2009 Elsevier Ltd. All rights reserved.

Transition metal-catalyzed cross-coupling reactions of alkenyl triflates (such as **2a**) and phosphates (such as **2b**) allow a[1] retrosynthetic (hence, strategic) relationship between a substituted alkenyl carbon atom (as in **3**) and a (enolizable) carbonyl carbon atom (as in **1**). Due to geometric constraints in their structure, such transformations are generally more useful in the cases of cyclic carbonyl derivatives (Scheme 1).

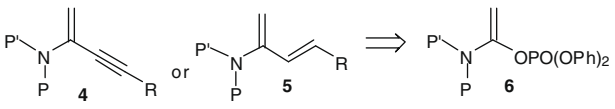
This chemistry has been particularly fruitful in the construction of more functionalized heterocycles from lactones[2] and lactams.[3] In recent years, there has been a growing interest in the catalyzed cross-coupling reactions of lactam-derived ketene aminal phosphates (α-phosphoryloxy enecarbamates) as alternatives to the corresponding triflates.[4,5] A reason for this is cost as more affordable chlorophosphate reagents (typically $(PhO)_2POCl$) are employed in the synthesis of enol phosphates. Moreover, it has also been shown that these compounds may be more stable than the triflate counterparts.[5]

Our attention was drawn to the study of the synthesis of functionalized *N*-carbonyl enamines **4** and **5** (Scheme 2), potential precursors of functionalized carbon frameworks. These compounds could be prepared via cross-coupling of ketene aminal phosphate **6**, which could be derived from *N,N*-diprotected acetamides. Only over the past two years, the first studies on synthesis and reactions of acyclic ketene aminal phosphates, have been disclosed.[6,7] We restricted our choice of precursors **6** to compounds bearing two removable protecting groups at the nitrogen atom. This may broaden the scope of the methodology. As the following discussion will show, a good deal of work had to be done to reconcile a suitable substitution pattern and stability.

Our first hypothesis was that phosphate **6a** (Scheme 3), bearing a nitrogen atom protected with Boc, might serve our purpose of scrutinizing the reactivity of this class of synthetic blocks. Thus, *N*-benzyl acetamide **7** (prepared by acetylation of $BnNH_2$) was protected with a Boc group via the usual procedure to give *N,N*-diprotected acetamide **7**. This substance was subjected to enolization



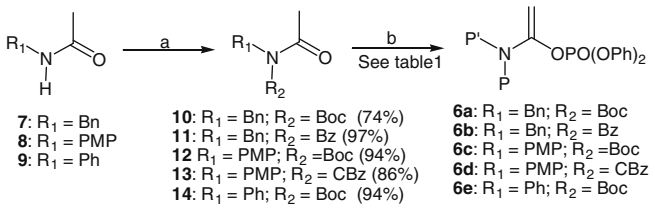
Scheme 1. Transformation of carbonyl compounds into olefins via alkenyl phosphates and triflates.



Scheme 2. Acetamide-derived ketene aminal phosphates **6** as precursors of enynes **4** and dienes **5**.

* Corresponding author. Tel.: +55 21 2652 6792; fax: +55 21 2562 6512.
E-mail address: abcsimas@nppn.ufrj.br (A.B.C. Simas).

0040-4039/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tetlet.2009.09.159



Scheme 3. Conversion of N-substituted acetamides into ketene aminal phosphates **6**. Reagents and conditions: (a) for **10**, **12** and **14**: DMAP, TEA, $(Boc)_2O$, CH_2Cl_2, 0 °C (30 min), rt (24 h); for **11**: DMAP, TEA, BzCl, CH_2Cl_2, 0 °C (30 min), rt (24 h); for **13**: (i) LDA, −78 °C, THF, 1 h; (ii) CbzCl, −78 °C (30 min), rt (24 h).

Table 1
Synthesis of ketene aminal phosphates **6**

Entry	Acetamide[a]	Product[b]	Yield[c] (%)	Stability
1	**10**	**6a**	38	Poor
2	**11**	**6b**	50	Low
3	**12**	**6c**	70	Fair
4	**13**	**6d**	87	Good
5	**14'**	**6e**	50	Good

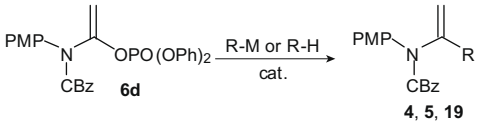
[a] See Scheme 3.
[b] Reagents and conditions: for **6a**, **6b**: (i) NHMDS, THF, −78 °C, 1 h; (ii) $ClOP(OPh)_2$, −78 °C (30 min) to 0 °C; for **6c**, **6d**, **6e**: (i) LDA, −78 °C, THF, 1 h; (ii) $ClPO(OPh)_2$, THF, −78 °C (1 h) to −20 °C.
[c] Pure compounds.

and treated with $(PhO)_2POCl$ to produce the desired phosphate, **6a** (Table 1, entry 1). This substance, however, proved to be too labile to be synthetically useful.[8] The unsatisfactory yield in the preparation of this substance may possibly result from its low stability. It is noteworthy that we could still obtain a pure sample of **6a**. We then presumed that a decrease in electron density at the olefinic portion of substances **6** would make them more stable. Thus, we elected *N*-benzoyl derivative **6b** (Scheme 3) as the next potential precursor of substances **4** and **5**. N-Benzoylation of acetamide **10** gave imide **11** which was transformed into phosphate **6b** as it had been done with counterpart **6a** (Table 1, entry 2). The use of the stronger electron-withdrawing benzoyl group did make phosphate **6b** more stable than **6a**. The stability of **6b** was limited, tough. Even when stocked under cooling, significant degradation of this compound was noticed. We nonetheless made the first attempts of cross-coupling reactions of this substance. Sonogashira coupling with phenylacetylene, under Negishi's modified protocol (vide infra) could be carried out but in low yield (13%). Although the immediate use of rather unstable phosphates in crude form in couplings is possible and could make such intermediates (especially more robust **6b**) useful, this is not desirable. Indeed, it would make the optimization of coupling reactions, if needed, far more difficult or even make the use of phosphates unviable in cases requiring extensive experimentation.

The latter results confirmed the stabilization role of the protecting groups at the nitrogen atom of substances **6**. An attempt to make them even more robust by further tuning the electron density at enol phosphate C–C double bond was made. Thus, we planned the use of both *p*-methoxyphenyl (PMP) and an alcoxycarbonyl group for protection of the nitrogen atom of **6**. We expected that the combination of two electron-withdrawing protecting groups might foster significant stabilization on substances **6**. Thus, *N*-acetamide derived from *p*-anisidine, **8** (Scheme 3), was protected with either a Boc or CBz group, under suitable conditions, giving derivatives **12** and **13**, respectively. Enolization of these compounds, followed by treatment with the chlorophosphate reagent, led to ketene aminal phosphates **6c** and **6d**, respectively (Table 1, entries 3 and 4). LDA as base afforded better results compared to NaHMDS or KHMDS. As anticipated, we found that both compounds are substantially more stable than **6b**. However, **6d** showed a clearly higher stability compared to **6c**, which could also be synthetically useful. The lesser stability of phosphate **6c**, bearing the Boc group, is certainly intriguing. Some of the prepared samples of **6d** withstood stocking under cooling for several months with little noticeable degradation. In order to gain more insight into the impact of the *O*-alkyl carbamate function on the stability of substances **6**, we synthesized known phosphate **6e**[6a] (Table 1, entry 5) (single experiment). Contrary to analogous **6c**, this *N*-Boc-containing substance showed very good stability. This proves that it is the combination of both Boc and PMP group which brings about lesser stability. We tentatively suggest that the electron rich olefinic moiety weakens the $(CH_3)_3C$–O bond (in **6c**) more substantially than the Bn–O (in **6d**) as a tertiary carbocation may be formed the C–O bond cleavage in the former case. The stability differences among phosphates **6** were consistent and significant.

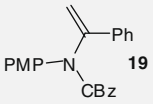
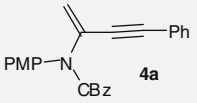
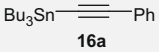
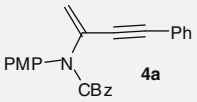
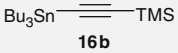
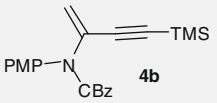
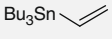
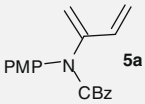
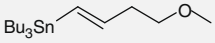
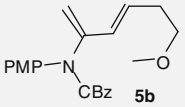
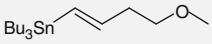
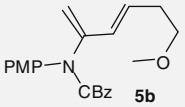
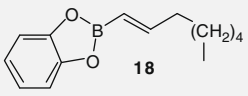
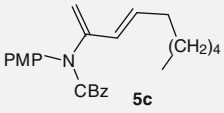
With robust phosphate **6d** in hand, the study on catalyzed cross-coupling reactions was initiated (Scheme 4, Table 2). As a comparison to the limited literature data on similar substances,[6,7] we have also assayed phosphate **6d** in a Suzuki coupling with $PhB(OH)_2$.[9] The successful formation of 2-phenyl enecarbamate **19** (Table 2, entry 1) parallels those previous results and confirms the usefulness of **6d** as well. Sonogashira reaction[10] of **6d** with phenyl acetylene, **15**, in the presence of $ZnCl_2/Et_3N$ (Negishi's version),[11] led to desired enyne **4a** albeit in moderate yield (50% based upon recovered **6d**; note the lower yield in the reaction of **6b**) (Table 2, entry 2). The classic condition for the same reaction (use of CuI) did not afford any detectable amount of product. Satisfyingly, we found that the Stille coupling[12] involving 1-stannylated derivative **16a**, under Farinás conditions,[13] led to enyne **4a** in good yield (entry 3) in a fast reaction run under mild condition. The catalytic system based on arsine ligand is knowingly less reactive in the oxidative addition than transmetalation step of the catalytic cycle. From these facts and the good result in the catalyzed reaction of **6d** with **16a** (entry 3), we presume that the low efficiency in the reaction of terminal acetylene **15** (entry 2), wherein a PPh_3-based catalyst is employed, may be originated by a slow transmetalation, and not due to a problem in oxidative addition. It appears unlikely that the problem is related to the in situ metalation (with $ZnCl_2$), as Negishi group reported good results of application of this protocol in reactions of the same co-substrate (**15**) run at room temperature. Indeed, we found that the reaction of **6d** with more acidic ethyl propiolate, under the same conditions, produced the alkynyl-substituted product in lower yield (26%). The activation via stannylation also allowed the synthesis of TMS-substituted enyne **4b** (Entry 4) in moderate yield. Some yield loss may have occurred during work-up and purification as we observed that product **4b** shows higher lability compared to the other products presented here.

The Stille reaction of **6d** with vinyl stannane **17a** also proved feasible (Entry 5). Diene **5a** was obtained in high yield. Conversely, when the same catalytic protocol was applied to the reaction of 2-alkyl substituted stannane **17b**,[14] the expected product **5b** was not formed (Entry 6). In this reaction, both phosphate **6d** and vinyl stannane **17b** were consumed, with the latter reactant being consumed at a fast rate. Satisfyingly, this problem was overcome by employment of the classical Stille protocol in the reaction of the



Scheme 4. Palladium-catalyzed cross-couplings of compound **6d**.

Table 2
Cross-couplings of phosphate **6d**[a]

Entry	R–M/R–H	Conditions	Products	Yield (%)
1	$PhB(OH)_2$	$PdCl_2(PPh_3)_2$, Na_2CO_3, EtOH, THF, 80 °C, 20 min	 **19**	64
2	 **15**	$Pd(OAc)_2$, PPh_3, $ZnCl_2$, THF/TEA (2:1), 24 h	 **4a**	39
3	 **16a**	$Pd_2dba_3{\cdot}CHCl_3$, $AsPh_3$, DIPEA, NMP, 2 h	 **4a**	65
4	 **16b**	$Pd_2dba_3{\cdot}CHCl_3$, $AsPh_3$, DIPEA, NMP, rt, overnight	 **4b**	46–51
5	 **17a**	$Pd_2dba_3{\cdot}CHCl_3$, $AsPh_3$, DIPEA, NMP, rt, overnight	 **5a**	83
6	 **17b**	$Pd_2dba_3{\cdot}CHCl_3$, $AsPh_3$, DIPEA, NMP, rt, overnight	 **5b**	–
7	 **17b**	$Pd(PPh_3)_4$, LiCl, THF, 70 °C, 2 h	 **5b**	64
8	 **18**	$PdCl_2(PPh_3)_2$, Na_2CO_3 aq, THF, 65 °C, 2.5 h	 **5c**	66

[a] See Scheme 4.

same vinyl stannane **17b** (Entry 7). Interestingly, $PdCl_2(PPh_3)_2$ could not replace $Pd(PPh_3)_4$ in this transformation, as no reaction occurred in the presence of the former catalyst. This failed experiment could be rescued when a mixture $Pd_2dba_3{\cdot}CHCl_3$ and PPh_3 in THF was added and the resulting mixture was heated. Finally, the successful reaction of **6d** and boronate **18**[15] shows the Suzuki couplings to be alternative for the synthesis of dienes **5** (Entry 8).[16] In summary, we identified acetamide-derived ketene aminal phosphate, **6d**, as a quite stable synthetic block.[17] The stability of phosphates **6** depends heavily on the substitution pattern of the nitrogen atom. Our study established that these compounds undergo palladium-catalyzed cross-couplings to produce enynes[18a] and dienes.[18b,c] We have shown that the activation of 1-alkynes via stannylation expedites the production of the desired enynes. Moreover, an interesting differential behavior of alkyl-substituted-1-stannyl olefins in Stille couplings of phosphate **6d**, under the Farina protocol, has been uncovered. To the best of our knowledge, flexible synthetic methodologies for compounds with the same substitution pattern have not been previously reported.[19,20] The enynes and dienes built by the methodology advanced herein are potential precursors of natural products or other bioactive substances.

Acknowledgment

FAPERJ, CNPq, CAPES for funding and/or fellowships; CNRMN-IBM/UFRJ and Central Analítica-NPPN for analytical data.

References and notes

1. *Palladium in Organic Synthesis*; Tsuji, J., Ed.; Springer: Berlin/Heidelberg, 2005.
2. (a) Nicolaou, K. C.; Shi, G. Q.; Gunzner, J. L.; Gärtner, P.; Yang, Z. *J. Am. Chem. Soc.* **1997**, *119*, 5467. and cited refs; (b) Fugami, K.; Oshima, K.; Utimoto, K. *Chem. Lett.* **1987**, 2203; (c) See Ref. 6d for an updated review.
3. (a) Occhiato, E. G.; Trabocchi, A.; Guarna, A. *J. Org. Chem.* **2001**, *66*, 2459; (b) Occhiato, E. G.; Trabocchi, A.; Guarna, A. *Org. Lett.* **2000**, *2*, 1241; (c) Luker, T.; Hiemstra, H.; Speckamp, W. N. *Tetrahedron Lett.* **1996**, *37*, 8257; (d) Bernabé, P.; Rutjes, F. P. J. T.; Hiemstra, H.; Speckamp, W. N. *Tetrahedron Lett.* **1996**, *37*, 3561; (e) Okita, T.; Isobe, M. *Tetrahedron* **1995**, *51*, 3737; (f) Foti, C. J.; Comins, D. L. *J. Org. Chem.* **1995**, *60*, 2656.
4. (a) Nicolaou, K. C.; Shi, G.; Namoto, K.; Bernal, F. *Chem. Commun.* **1998**, 1757; (b) Jiang, J.; DeVita, R. J.; Doss, G. A.; Goulet, M. T.; Wyvratt, M. J. *J. Am. Chem.*

Soc. **1999**, *121*, 593; (c) Coudert, G.; Buon, C.; Chacun-Lefevre, L.; Rabot, R.; Bouyssou, P. *Tetrahedron* **2000**, *56*, 605.
5. Occhiato, E. G. *Mini-Rev. Org. Chem.* **2004**, *1*, 149.
6. (a) Cottineau, B.; Gillaizeau, I.; Farard, J.; Auclair, M.; Coudert, G. *Synlett* **2007**, *12*, 1925; (b) Fuwa, H.; Sasaki, M. *Chem. Commun.* **2007**, 2876; (c) Fuwa, H.; Sasaki, M. *Org. Lett.* **2007**, *9*, 3347; (d) Fuwa, H.; Sasaki, M. *J. Org. Chem.* **2009**, *74*, 212.
7. de Sales, D. L. *Master Degreés Dissertation*; Universidade Federal do Rio de Janeiro: Brazil, 2006.
8. The following works dealt with the stability problem in cyclic ketene aminal phosphates and triflates. Our experience has shown that the acyclic counterparts may be as labile as the ones derived from five-membered lactams (Ref. 8a): (a) Lepifre, F.; Clavier, S.; Bouyssou, P.; Coudert, G. *Tetrahedron* **2001**, *57*, 6969; (b) See Ref. 3c
9. (a) Suzuki, A. *J. Organomet. Chem.* **1999**, *576*, 147; (b) Miyaura, N.; Suzuki, A. *Chem. Rev.* **1995**, *95*, 2457.
10. Sonogashira, K. *J. Organomet. Chem.* **2002**, *653*, 46.
11. Negishi, E.; Anastásia, L. *Org. Lett.* **2001**, *3*, 3111.
12. Stille, J. K. *Angew. Chem., Int. Ed. Engl.* **1986**, *25*, 508; Kosugi, M.; Fugami, K. *J. Organomet. Chem.* **2002**, *653*, 50.
13. Farina, V.; Krishnamurthy, V.; Scott, W. J. *Org. React.* **1997**, *50*, 1; Farina, V.; Krishnan, B.; Marshall, D. R.; Roth, G. P. *J. Org. Chem.* **1993**, *58*, 5434; Farina, V.; Krishnan, B. *J. Am. Chem. Soc.* **1991**, *113*, 9585; Simas, A. B. C.; de Sales, D. L.; Cavalcante, S. F. A.; de Medeiros, C. M.; Moraes, S. H. S.; de Carvalho, E. M. *Lett. Org. Chem.* **2008**, *5*, 587.
14. Stannane **17b** was prepared by hydrostannylation of 3-butyn-1-ol under the conditions advanced by Chong's group, followed by *O*-methylation: Darwish, A.; Lang, A.; Kim, T.; Chong, J. M. *Org. Lett.* **2008**, *10*, 861.
15. Brown, H. C.; Gupta, S. K. *J. Am. Chem. Soc.* **1972**, *94*, 4370.
16. Miyaura, N.; Yamada, K.; Suginome, H.; Suzuki, A. *J. Am. Chem. Soc.* **1985**, *107*, 972.
17. *Synthesis of ketene aminal phosphate* **6d**: A solution of BuLi 1.3 M in hexanes (1.54 mL) was added to *i*-Pr_2NH (0.31 mL, 2.24 mmol) in dry THF (1.5 mL) under Ar at 0 °C. After 20 min, amide **13** (0.384 g, 1.60 mmol) in dry THF (1.5 mL) was added at −78 °C and the mixture was stirred for 1 h under the same conditions. Then, a solution of $(PhO)_2POCl$ (0.41 mL, 2.00 mmol) in THF (1.5 mL) was added dropwise and stirring proceeded for 1 h. Then, 5% aq NH_4OH was added and after regular work-up, the obtained residue was purified by flash chromatography (neutralized silica gel, 2% TEA) to afford phosphate **6d** (0.383 g, 87%).^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35–7.06 (m, 9H), 6.80 (d, J = 12.1 Hz, 2H), 5.26 (s, 1H), 5.15 (s, 2H), 4.89 (dd, J = 3.0 Hz, J = 2.0 Hz, 1H), 3.79–3.76 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.6 (C), 153.9 (C), 150.3 (C), 146.1 (C), 135.8 (C), 132.2 (C), 129.8 (CH), 127.9 (CH), 125.6 (CH), 120.1 (CH), 114.3 (CH), 97.7 (CH_2), 68.1 (CH_2), 55.4 (CH_3). MS (ESI): m/z 532.2 ($M+H^+$), 554.2 (($M+Na^+$).
18. (a) *Synthesis of enyne* **4a** (Stille coupling): A mixture of $Pd_2dba_3{\cdot}CHCl_3$ (0.013 g, 0.013 mmol) and $AsPh_3$ (0.032 g, 0.103 mmol) in deoxygenated NMP (0.5 mL) was stirred for 10 min under Ar at rt. Then, phosphate **6d** (0.137 g, 0.258 mmol) in deoxygenated NMP (1.5 mL) was added followed by a solution of stannane **16a** (0.201 g, 0.515 mmol) in NMP (1.5 mL) and DIPEA (0.067 g, 0.515 mmol). The reaction proceeded overnight under these conditions. A 4:6 EtOAc/hexane mixture was added and the resulting mixture was washed with H_2O, dried with Na_2SO_4, and evaporated under reduced pressure. The residue was purified by flash chromatography (neutralized silica gel, 2% TEA) to afford enyne **4a** (0.065 g, 65%).^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29–7.24 (m, 5H), 6.88 (s, 2H), 6.86 (s, 2H), 5.54 (s, 1H) 5.50 (s, 1H), 5.21 (s, 2H), 3.75 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.5 (C), 154.3 (C), 136.3 (C), 134.1 (C), 131.7 (C), 129.5 (CH), 128.7 (CH), 128.5 (CH), 128.3 (CH), 127.8 (CH), 122.4 (C), 119.9 (CH), 118.7 (CH_2), 115.5 (CH), 114.2 (CH), 89.6 (C), 86.4 (C), 67.7 (CH_2), 55.5 (CH_3). MS (ESI): m/z 384.2 ($M+H^+$), 406.3 (($M+Na^+$). Calcd (%) for $C_{25}H_{21}NO_3$: C, 78.31; H, 5.52; N, 3.65. Found: C, 77.57; H, 5.84; N, 3.66. IR (film): 2930, 1701, 1246 cm^{-1}. (b) *Synthesis of diene* **5b**: A mixture of phosphate **6d** (0.116 g, 0.218 mmol), stannane **17b** (0.164 g, 0.437 mmol), LiCl (0.028 g, 0.656 mmol) and $Pd(PPh_3)_4$ (0.012 g, 0.011 mmol) in dry THF (5.0 mL) was refluxed under Ar for 2 h. Finally, the reaction mixture was evaporated under reduced pressure and the residue was purified by flash chromatography (neutralized silica gel, 2% TEA) to afford diene **5b** (0.051 g, 64%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38–7.29 (m, 5H), 7.24 (d, J = 8.80, 2H), 6.82 (d, J = 8.90, 2H), 6.13 (s, 1H), 5.79 (m, 1H) 5.22 (s, 1H), 5.18 (s, 2H), 5.06 (s, 1H), 3.77 (s, 3H), 3.39 (t, J = 6.72, 2H), 3.28 (s, 3H), 2.33 (q, J = 6.72, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.9 (C), 154.2 (C), 145.7 (C), 136.0 (C), 134.6 (C), 128.9 (CH), 128.5 (CH), 127.9 (CH), 127.44 (CH), 127.37 (CH), 125.9 (CH), 114.6 (CH_2), 113.4 (CH), 71.3 (CH_2), 66.9 (CH_2), 58.1 (CH_3), 54.9 (CH_3), 32.1 (CH_2). MS(ESI): m/z 368.2 ($M+H^+$), 390.1 ($M+Na^+$). Calcd (%) for $C_{22}H_{25}NO_4$: C, 71.91; H, 6.86; N, 3.81. Found: C, 71.73; H, 6.84; N, 3.86. (c) *Synthesis of diene* **5c**: phosphate **6d** (0.1029 g, 0.194 mmol) in dry THF (2.0 mL) was added to a stirred solution of $PdCl_2(PPh_3)_2$ (0.0135 g, 0.019 mmol) in dry THF (0.5 mL). After 15 min, a 0.6 M solution of boronate **18** (0.77 mL, 0.290 mmol), aq 2 M Na_2CO_3 (0.29 mL, 0.581 mmol) and three drops of EtOH were added and the resulting mixture was heated at 65 °C for 2.5 h. After the usual aqueous work-up, the obtained residue was purified by flash chromatography (neutralized silica gel, 2% TEA) to afford diene **5c** (0.049 g, 66%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21–6.71 (m, 9H), 5.71 (m, 1H), 5.28 (s, 1H), 5.26 (s, 1H), 4,94 (s, 1H), 3.69 (s, 3H), 2.09 (t, J = 2.10, 2H), 1.15 (m, 6H), 0.77 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.5 (C), 154.3 (C), 136.3 (C), 134.1 (C), 131.7 (C), 129.5 (CH), 128.7 (CH), 128.5 (CH), 128.3 (CH), 127.8 (CH), 122.4 (C), 119.9 (CH), 118.7 (CH_2), 115.5 (CH), 114.2 (CH), 89.6 (C), 86.4 (C), 67.7 (CH_2), 55.5 (CH_3). MS (ESI): m/z 384.2 ($M+H^+$), 406.3 ($M+Na^+$). IR (film): 2930, 1701, 1246 cm^{-1}.
19. Enynes and dienes displaying similar functional features, for the most part, have been incidentally generated: (a) Meffre, P.; Gauzy, L.; Branquet, E.; Durand, P.; Le Goffic, F. *Tetrahedron* **1996**, *52*, 11215; (b) Reginato, G.; Mordini, A.; Caracciolo, M. *J. Org. Chem.* **1997**, *62*, 6187.
20. For a designed methodology towards similar enyne via a double elimination: Saito, S.; Uchiyama, N.; Gevorgyan, V.; Yamamoto, Y. *J. Org. Chem.* **2001**, *65*, 4338.