A novel one-pot route to cyclopenta[*b*]indole *via* the palladium-catalysed carbonylative cross-coupling reaction of indolylborate with prop-2-ynyl carbonate

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A novel one-pot protocol for the formation of cyclopenta[*b*]indole is developed *via* the palladium catalysed carbonylative cross-coupling reaction.

The marked facility with which palladium complexes undergo an oxidative addition to prop-2-ynyl halides and esters in a S_N2' manner to form allenylpalladium complexes has been documented, as has the susceptibility of the resulting palladium complexes to a wide variety of chemical transformations.[1] As part of our ongoing studies, we have previously demonstrated the use of the allenylpalladium complexes for the construction of 2-allenylindoles *via* the palladium-catalysed cross-coupling reaction of indolylborate **1** with prop-2-ynyl carbonates.[2] Despite the known reactivity of the allenylpalladium complexes under carbonylation conditions in the presence of a nucleophile producing allenic esters, amides, and ketones,[3] its use for the formation of allenyl ketones *via* the carbonylative cross-couping reaction is unknown. This posed the interesting question of whether the palladium-catalysed reaction of borate **1** with prop-2-ynyl carbonate can be effective under carbonylation conditions.

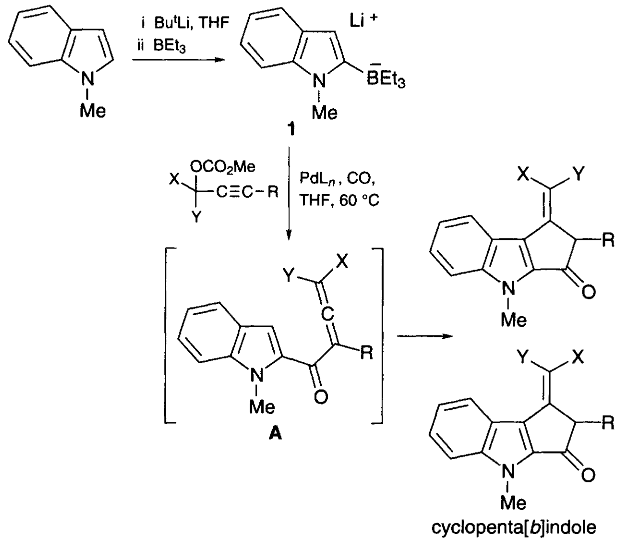
Table 1 Cyclopenta[*b*]indoles **4** from borate **1** and carbonates **2**

Carbonate	PdL$_n$	Yield of **4**[a] (%)
2a	PdCl$_2$(PPh$_3$)$_2$	58
2a	Pd(OAc)$_2$ + 2PPh$_3$	60
2a	Pd(PPh$_3$)$_4$	63
2b	PdCl$_2$(PPh$_3$)$_2$	60
2c	PdCl$_2$(PPh$_3$)$_2$	61
2d	PdCl$_2$(PPh$_3$)$_2$	44 (14)[b]
2e	PdCl$_2$(PPh$_3$)$_2$	—[c]
2f	Pd(OAc)$_2$ + 2PPh$_3$	— (56)[d]
2f	Pd(PPh$_3$)$_4$	— (34)[d]
2f	PdCl$_2$(PPh$_3$)$_2$	— (38)[d]

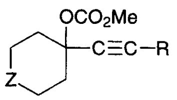
[a] All yields based on 1-methylindole. [b] Yield of allene **8b** (%). [c] No cross-coupling products. [d] Yield of allene **8a** (%).

The feasibility of the palladium-catalysed carbonylation was first tested with borate **1** and carbonate **2** (Table 1); thus, cyclopenta[*b*]indole **4**,[4] a basic framework of indole alkaloides such as yuehchukene, pasparine and paxilline, could be isolated in a one-pot manner (Scheme 1).

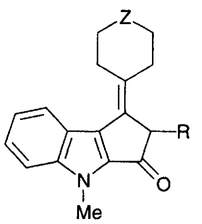
In general, the present carbonylation reaction can be effected by simply stirring a mixture of borate **1** (generated *in situ* from



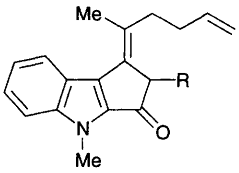
Scheme 1



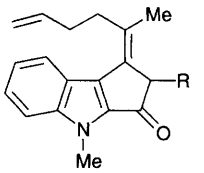
2 (Z = CH$_2$)
a R = Me
b R = (CH$_2$)$_4$OTHP
c R = (CH$_2$)$_3$Cl
d R = Ph
e R = SiMe$_3$
f R = H
3 (Z = NBoc)
a R = Me
b R = Ph



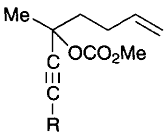
4 (Z = CH$_2$)
a R = Me
b R = (CH$_2$)$_4$OTHP
c R = (CH$_2$)$_3$Cl
d R = Ph
5 (Z = NBoc)
a R = Me
b R = Ph



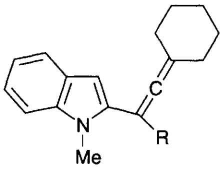
E-**7a** R = Ph
E-**7b** R = Bu



Z-**7a** R = Ph
Z-**7b** R = Bu



6a R = Ph
b R = Bu



8a R = H
b R = Ph

1-methylindole and Bu^{t}Li, followed by treatment with triethylborane in THF) and 1.5 equiv. of prop-2-ynyl carbonate (**2**, **3**, **6**) in the presence of palladium complex (5 mol%) under 10 atm of carbon monoxide pressure at 60 °C for 12 h.

The carbonylative cross-coupling reaction proceeded to produce cyclopenta[*b*]indole **4** when acetylenic carbon of **2** bears a substituent (such as phenyl and alkyl); otherwise, any cross-coupling product could not be seen in attempted reactions with **2e** bearing the sterically demanding trimethylsilyl group. Allenylindole **8a** was formed solely on the reaction of **1** with terminal alkyne **2f**. Furthermore, carbonates **3** could also be subjected to the carbonylation reaction, providing cyclopenta[*b*]indoles (**5a** in 62%; **5b** in 44%). This one-pot process should involve the intermediary formation of allenyl ketone **A**, and subsequent nucleophilic addition of the C-3 carbon of indole to the internal allenic carbon of **A** (Scheme 1). On treating **1** with **6a** and **6b**, geometrical mixtures of *E*-**7a** and *Z*-**7a** (in 38%) and *E*-**7b** and *Z*-**7b** (in 59% yield) were obtained, respectively, in the ratio 1 : 1, where the axially dissymmetric features of the allene unit of **A** allowed the generation of the geometrical isomers.

In summary, the feasibility of the palladium-catalysed carbonylative cross-coupling reaction of borate **1** with prop-2-ynyl carbonates, accompanied by subsequent cyclisation, is apparent, which provides a new one-pot procedure for the generation of cyclopenta[*b*]indoles.

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