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Synthesis of pyrrolo[2,3-*c*]2,7-naphthyridine derivatives by cascade heterocyclization reaction of 2-amino-4-cyanomethyl-6-dialkylamino-3,5-pyridinedicarbonitriles

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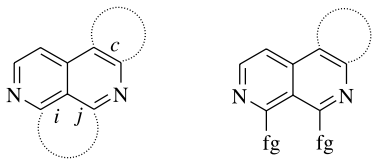
Abstract—Alkylation of the title pyridinedicarbonitriles with *N*-substituted chloroacetamides was found to give 5,6-diamino-8-dialkylamino-2,3-dihydro-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitriles. The structure of obtained compounds was unambiguously confirmed by X-ray crystallographic study. The heterocyclization reaction proceeded regioselectively involving 3-CN group of the starting pyridines without participation of 5-CN. The reasons of the selectivity were discussed. An interaction of prepared naphthyridine derivatives with acetic acid anhydride and cyclohexanone yielded 2-dialkylamino-6,8,9,10-tetrahydro-5-methyl-9-oxopyrimido[4,5,6-*ij*]-pyrrolo[2,3-*c*]2,7-naphthyridine-1-carbonitriles and 2-dialkylamino-4,5,6,8,9,10-hexahydro-9-oxospiro{pyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]-2,7-naphthyridine-5,1′-cyclohexane}-1-carbonitriles, respectively. All fused 2,7-naphthyridines obtained were derivatives of novel heterocyclic systems.

1. Introduction

2,7-Naphthyridine nucleus is known to be a part of a large number of alkaloids.[1–11] Thus, alangimaridine,[1] isoalamarine,[2] alamaridines,[3] nauclefine,[4,5] naulafine,[6] normalindine,[7] eudistones,[8] cystodytins,[9] kuanoniamines[10] and meridine[11] can be mentioned as examples of natural condensed 2,7-naphthyridines. Many of these alkaloids consist of 2,7-naphthyridine moiety fused at the sides *i*,*j* and *c*[8–11] (Fig. 1, structure **1**). Hence the [*c*]fused 2,7-naphthyridines bearing functional groups at appropriate positions



1 **2**

Figure 1. Dashed lines establish annulated rings. 'fg' is a functional group.

(Fig. 1, structure **2**) could be suitable precursors for natural compounds and their analogues. Therefore, the synthesis of the naphthyridines of type **2** is of interest.

While a considerable number of 2,7-naphthyridines of type **2** fused with six-membered rings has been described in the literature (for reviews see[12–16]), corresponding derivatives condensed with five-membered heterocycles have been less investigated.[17–28] Thus, pyrazolo-,[17,21] isoxazolo-,[21] cyclopenta-,[18] thieno-,[19,20,22–24,26–28] furo-,[22–24] and imidazo-[25] annulated 2,7-naphthyridines **2** were prepared. At the same time 2,7-naphthyridines fused at the side *c* with pyrrole nucleus are hitherto unknown. This prompted us to look for approaches to the pyrrolonaphthyridines of type **2**.

2. Results and discussion

Most of the above mentioned compounds **2** were obtained by the central pyridine ring formation starting from the suitable pyridine and five-membered cyclic precursors in one or several steps.[17–25] An alternative approach, including ring annulations to the readily available 2,7-naphthyridine, was applied for thieno derivatives only.[26,27] Over the last years so called cascade reactions have had an increasing

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importance in heterocyclic chemistry,[29–32] since they allow creation of two or more rings at once at the expense of sequential chemical transformations induced one by another. It seems to be the most economical method for condensed heterocycles preparation. Thus, recently cascade process involving Smiles rearrangement and two sequential nucleophilic additions to nitrile has been used for thieno[2,3-*c*]2,7-naphthyridine synthesis.[28]

Previously we have shown utility of the readily available pyridines **4**–**6** for 2,7-naphthyridine derivative preparation by alkoxide induced 1,5-dinitrile cyclization reaction.[33] Continuing our researches in this field we assumed compounds **4**–**6** to be suitable starting materials for the target pyrrolonaphthyridines synthesis via cascade reaction with chloroacetamides. Thus, alkylation of the malonodinitrile, ethyl cyanoacetate and 2-benzothiazoleacetonitrile with *N*-substituted chloroacetamides was reported to yield aminopyrrolones **3**[34–40] (Fig. 2). Therefore, the similar alkylation of the pyridines **4**–**6** also containing a CH_2CN moiety should afford the intermediates **7** (Scheme 1) which should undergo further cyclization to give desired pyrrolonaphthyridines. However, there are two possibilities for ring closure in the intermediates **7** with participation of 3-CN or 5-CN leading to the isomers **8**–**10** or **11**, respectively. Of course, a mixture of products could also be formed. Nevertheless, reaction of the derivatives **4**–**6** with *N*-substituted chloroacetamides in ethanol in the presence of K_2CO_3 was found to result in the individual compounds isolated in 50–70% yields. Since the isomers **8**–**10** and **11** were difficult to distinguish using spectral data the structures **8**-**10** were assigned to the products on the basis of X-ray crystallographic study carried out for derivative **9b** (Fig. 3).

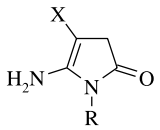


Figure 2. X=CN, CO_2Et, 2-benzothiazolyl.

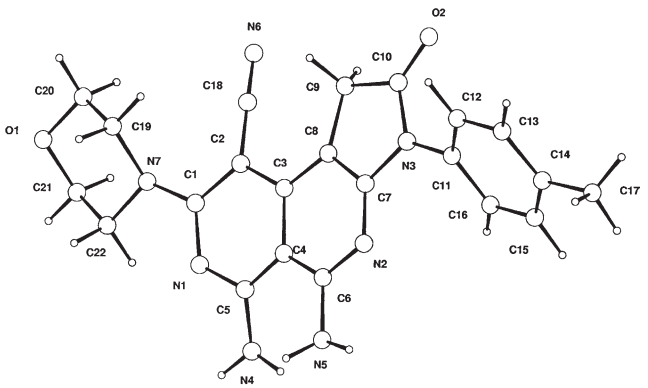
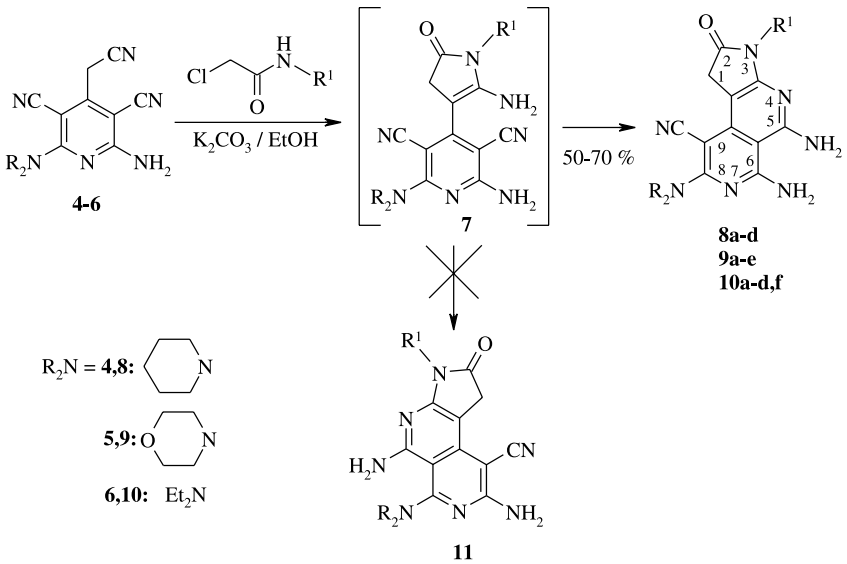


Figure 3. X-ray molecular structure of compound **9b** with the atom numbering used in the crystallographic analysis.

According to the crystal data† pyrrole and pyridine ring N2–C6–C4–C3–C8–C7 of compound **9b** are coplanar (with precision of 0.03 Å). Phenyl substituent is turned out from this plane at the angle 72°. The ring N1–C1–C2–C3–C4–C5 is slightly twisted. The atoms C1 and C5 are deviated from the other rings plane at −0.21 Å and +0.34 Å, respectively. Probably, this distortion is caused by interaction between amino groups, namely the formation of the intramolecular hydrogen bond N4–H···N5 with the length 3.01 Å and the angle N4–H–N5 150°. Of course, the



Scheme 1. R^1=**a**: 4-(*i*-Pr)C_6H_4, **b**: 4-$CH_3C_6H_4$, **c**: 3,4-$(MeO)_2C_6H_3$, **d**: 4-$MeOC_6H_4CH_2$, **e**: 3-ClC_6H_4, **f**: 4-ClC_6H_4.

† Crystallographic data (excluding structure factors) for the structure in this paper have been deposited with the Cambridge Crystallographic Data Center as supplementary publication number CCDC 230079. Copies of the data can be obtained, free of charge, on application to CCDC, 12 Union Road, Cambridge, CB2 1EZ, UK (fax:+44-1223-336033 or e-mail: deposit@ccdc.cam.ac.uk).

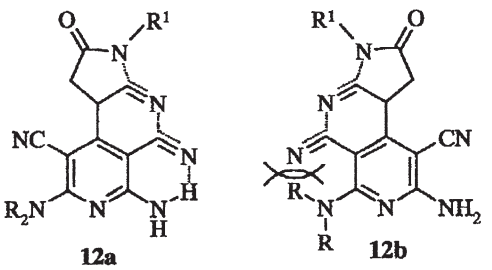


Figure 4.

distortions of the pyridine ring are small and the aromaticity of the naphthyridine moiety is not infringed.

It should be emphasized that there were no detectable amounts of the isomers **11** in the reaction mixtures. Hence the ring closure in the intermediates **7** proceeded regioselectively with participation of 3-CN. The selectivity was explained in the terms of transition state energy. Thus, nucleophilic additions to nitriles were assumed to occur synchronously or quickly one after another. Therefore, the transition states like **12** (Fig. 4) could be employed to describe the addition process. The transition state **12a** corresponding to the heterocyclization with 3-CN is additionally stabilized by intramolecular hydrogen bond. On the other hand the bulky dialkylamino group is not only unable to stabilize the alternative transition state **12b**, but seems to act destructively due to repulsion with neighbouring substituent. Consequently, the energy of the transition state **12a** is lower and the reaction proceeds through it resulting in pyrrolonaphthyridines **8**–**10**. It is noteworthy that predominant reactivity of 3-CN versus 5-CN in heterocyclization reactions of compounds **4**–**6** and related derivatives has been reported previously by us[33] and other researchers.[41]

The possibility of additional ring annulation to the compounds **8**–**10** using their amino groups was examined. Thus, treatment of the derivatives **8a**,**b**, **9e**, **10f** with excess of acetic acid anhydride or cyclohexanone yielded pyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]2,7-naphthyridines **13a**–**d** and spirocyclic compounds **14a**–**d**, respectively (Scheme 2). The structures of compounds **13** and **14** were confirmed by ^{1}H and ^{13}C NMR data. Furthermore the similar transformations are well known for 1,8-naphthalenediamine.[42–46] Apparently, fused naphthyridines **13** and **14** are the representatives of novel heterocyclic systems.

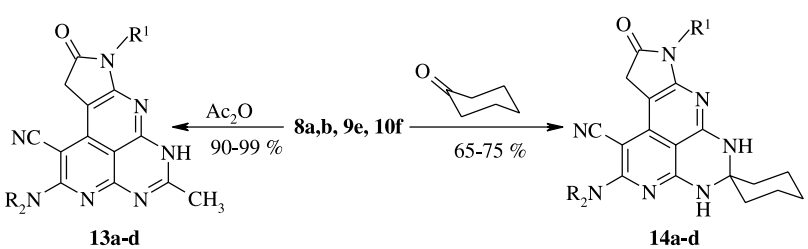
To summarize, the present investigation has resulted in a convenient method for the synthesis of pyrrolo[2,3-*c*]2,7-naphthyridines **8**–**10**, the derivatives of a hitherto unknown heterocyclic system. Furthermore, compounds **8**–**10** have been converted easily into more complex novel condensed and spirocyclic heterocycles **13**, **14**. It should be noted that the starting materials **4**–**6** were obtained by amination of 2-amino-6-chloro-4-cyanomethyl-3,5-pyridinedicarbonitrile (**15**) in quantitative yields.[33] The chloropyridine precursor **15** was in turn available from malonodinitrile and inorganic materials in two steps.[41] Hence derivatives **8**–**10** and **13**, **14** have been prepared from malonodinitrile in four and five steps, respectively. The other reagents used, such as amines, chloroacetamides, acetic anhydride and cyclohexanone, are also of general access. The simpler and cheaper sources for the preparation of complex heterocycles are difficult to be proposed. Of course, the corner-stone of the present synthetic pathway is the cascade heterocyclization reaction of the pyridines **4**–**6** occurred regioselectively with the 3-CN group. Moreover, potential of the pyridines **4**–**6** in heterocyclic synthesis is believed not to be limited to the present work and further research on their chemistry are in progress.

3. Experimental

The pyridines **4**–**6**[33] and chloroacetamides[47] were prepared as reported. Other reagents were commercially available. All melting points were determined in open capillary tubes in a Thiele apparatus and are uncorrected. ^{1}H and ^{13}C NMR spectra were recorded on a Mercury 400 (400 MHz for ^{1}H and 100 MHz for ^{13}C) spectrometer in DMSO-d_6 solutions. Chemical shifts (δ) are given in ppm downfield from internal $SiMe_4$. *J* values are in Hz. The purity of all compounds prepared was checked by ^{1}H NMR.

3.1. Pyrrolo[2,3-*c*]2,7-naphthyridines 8–10. General procedure

Powdered K_2CO_3 (0.41 g, 3.0 mmol) and chloroacetamide (2.5 mmol) were added to a hot solution of the pyridines **4**–**6** (2.5 mmol) in absolute ethanol (10 ml) and the



13,14	a	b	c	d
R_2N	N	N	O N	Et_2N
R^1	4-(*i*-Pr)C_6H_4	4-$CH_3C_6H_4$	3-ClC_6H_4	4-ClC_6H_4

Scheme 2.

resulting mixture was refluxed for 30–40 min. After cooling the precipitated solid was filtered, thoroughly washed with water, dried and recrystallized from an appropriate solvent to give compounds **8–10**.

3.1.1. 5,6-Diamino-2,3-dihydro-2-oxo-8-(1-piperidinyl)-3-[4-(*i*-propyl)phenyl]-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (8a). Yield 64%. White needles. Mp 269 °C (from dioxane); ν_{max} (KBr tablets) 3460, 3330, 2955, 2880, 2200, 1735, 1620, 1590, 1550, 1460, 1345, 1300, 1215, 1160, 1130, 1040, 850, 815, 710 cm^{-1}. δ_H 7.34 (2H, d, J=6.8 Hz, H_{R1}), 7.28 (2H, d, J=6.8 Hz, H_{R1}), 7.18 (2H, s, NH_2), 6.55 (2H, s, NH_2) 3.86 (2H, s, 1-CH_2), 3.69 (4H, m, NCH_2), 2.94 (1H, m, *i*-Pr), 1.59 (6H, m, $CH_2CH_2CH_2$), 1.23 (6H, d, J=6.4 Hz, *i*-Pr). δ_C 178.2 (2-CO), 163.3 (9a-C), 156.4 (5-C), 156.1 (6-C), 151.7 (8-C), 142.3 (3a-C), 135.1 (1-C_{R1}), 130.9 (4-C_{R1}), 128.6 (3,5-C_{R1}), 127.0 (2,6-C_{R1}), 116.9 (CN), 97.9 (5a-C), 89.6 (9b-C), 70.8 (9-C), 52.2 (2,6-C_{NR2}), 36.4 (1-C), 34.5 (*i*-Pr), 25.2 (3,5-C_{NR2}), 22.0 (4-C_{NR2}), 18.9 (*i*-Pr). Found: 67.9% C, 6.0% H, 22.4% N; $C_{25}H_{27}N_7O$ requires 68.0% C, 6.2% H, 22.2% N.

3.1.2. 5,6-Diamino-2,3-dihydro-3-(4-methylphenyl)-2-oxo-8-(1-piperidinyl)-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (8b). Yield 69%. White powder. Mp 296 °C (from DMF); ν_{max} (KBr tablets) 3465, 3340, 2970, 2200, 1735, 1595, 1450, 1300, 880, 760, 705, 630 cm^{-1}. δ_H 7.27 (4H, m, H_{R1}), 7.12 (2H, s, NH_2), 6.48 (2H, s, NH_2), 3.86 (2H, s, 1-CH_2), 3.69 (4H, m, NCH_2), 2.36 (3H, s, CH_3), 1.61 (6H, m, $CH_2CH_2CH_2$). δ_C 176.8 (2-CO), 168.1 (9a-C), 160.6 (5-C), 159.7 (6-C), 152.9 (8-C), 138.2 (3a-C), 138.0 (4-C_{R1}), 135.5 (1-C_{R1}), 129.5 (3,5-C_{R1}), 126.5 (2,6-C_{R1}), 119.8 (CN), 99.3 (5a-C), 91.2 (9b-C), 68.8 (9-C), 57.1 (2,6-C_{NR2}), 35.7 (1-C), 27.2 (3,5-C_{NR2}), 20.1 (CH_3), 17.4 (4-C_{NR2}). Found: 67.0% C, 5.5% H, 23.9% N; $C_{23}H_{23}N_7O$ requires 66.8% C, 5.6% H, 23.7% N.

3.1.3. 5,6-Diamino-2,3-dihydro-3-(3,4-dimethoxyphenyl)-2-oxo-8-(1-piperidinyl)-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (8c). Yield 54%. Yellow prisms. Mp 172 °C (from EtOH); ν_{max} (KBr tablets) 3430, 3330, 2980, 2850, 2200, 1730, 1620, 1520, 1490, 1280, 1140, 1025, 820 cm^{-1}. δ_H 7.17 (2H, s, NH_2), 7.04 (1H, d, J=8.4 Hz, 5-H_{R1}), 6.98 (1H, d, J=2.0 Hz, 2-H_{R1}), 6.90 (1H, dd, J=8.4, 2.0 Hz, 6-H_{R1}), 6.55 (2H, s, NH_2), 3.85 (2H, s, 1-CH_2), 3.80 (3H, s, OCH_3), 3.75 (3H, s, OCH_3), 3.70 (4H, m, NCH_2), 1.61 (6H, m, $CH_2CH_2CH_2$). δ_C 179.2 (2-CO), 165.2 (9a-C), 159.9 (5-C), 154.6 (6-C), 152.3 (8-C), 150.2 (3-C_{R1}), 149.3 (4-C_{R1}), 142.7 (3a-C), 128.1 (1-C_{R1}), 122.4 (CN), 117.4 (2-C_{R1}), 116.2 (6-C_{R1}), 111.9 (5-C_{R1}), 97.7 (5a-C), 86.1 (9b-C), 69.5 (9-C), 56.4 (OCH_3), 55.2 (OCH_3), 52.1 (2,6-C_{NR2}), 40.8 (1-C), 23.4 (3,5-C_{NR2}), 22.6 (4-C_{NR2}). Found: 62.9% C, 5.4% H, 21.6% N; $C_{24}H_{25}N_7O_3$ requires 62.7% C, 5.5% H, 21.3% N.

3.1.4. 5,6-Diamino-2,3-dihydro-3-[(4-methoxyphenyl)-methyl]-2-oxo-8-(1-piperidinyl)-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (8d). Yield 56%. White powder. Mp 192 °C (from EtOH); ν_{max} (KBr tablets) 3450, 3375, 2960, 2880, 2205, 1710, 1615, 1585, 1460, 1370, 1335, 1305, 1260, 1190, 1040, 920, 870 cm^{-1}. δ_H 7.27 (2H, d, J=7.2 Hz, H_{R1}), 7.11 (2H, s, NH_2), 6.84 (2H, d, J=7.2 Hz, H_{R1}), 6.57 (2H, s, NH_2), 4.74 (2H, s, N3-CH_2), 3.73 (2H, s, 1-CH_2), 3.70 (3H, s, OCH_3), 3.67 (4H, m, NCH_2), 1.59 (6H, m, $CH_2CH_2CH_2$). δ_C 179.5 (2-CO), 167.8 (9a-C), 159.0 (6-C), 157.6 (4-C_{R1}), 155.0 (5-C), 153.3 (8-C), 139.5 (3a-C), 131.5 (1-C_{R1}), 127.1 (2,6-C_{R1}), 115.7 (3,5-C_{R1}), 115.5 (CN), 98.5 (5a-C), 91.8 (9b-C), 68.6 (9-C), 57.3 (2,6-C_{NR2}), 55.3 (OCH_3), 47.2 (NCH_2), 38.1 (1-C), 29.5 (3,5-C_{NR2}), 26.1 (4-C_{NR2}). Found: 65.1% C, 5.5% H, 22.0% N; $C_{24}H_{25}N_7O_2$ requires 65.0% C, 5.7% H, 22.1% N.

3.1.5. 5,6-Diamino-2,3-dihydro-8-(4-morpholinyl)-2-oxo-3-[4-(*i*-propyl)phenyl]-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (9a). Yield 62%. White powder. Mp 242 °C (from DMF); ν_{max} (KBr tablets) 3420, 3360, 2920, 2195, 1725, 1650, 1575, 1490, 1350, 1275, 1205, 1170, 1115, 1030, 805, 720 cm^{-1}. δ_H 7.35 (2H, d, J=8.0 Hz, H_{R1}), 7.29 (2H, d, J=8.0 Hz, H_{R1}), 7.24 (2H, s, NH_2), 6.57 (2H, s, NH_2), 3.86 (2H, s, 1-CH_2), 3.69 (8H, m, NR_2), 2.95 (1H, m, *i*-Pr), 1.24 (6H, d, J=8.0 Hz, *i*-Pr). δ_C 179.3 (2-CO), 160.0 (6-C), 159.2 (5-C), 158.4 (9a-C), 148.6 (8-C), 141.5 (3a-C), 136.2 (1-C_{R1}), 132.7 (4-C_{R1}), 127.7 (2,6-C_{R1}), 127.4 (3,5-C_{R1}), 115.6 (CN), 102.7 (5a-C), 96.2 (9b-C), 70.5 (9-C), 66.1 (OCH_2), 51.9 (NCH_2), 39.6 (1-C), 32.9 (*i*-Pr), 20.3 (*i*-Pr). Found: 64.9% C, 5.8% H, 22.1% N; $C_{24}H_{25}N_7O_2$ requires 65.0% C, 5.7% H, 22.1% N.

3.1.6. 5,6-Diamino-2,3-dihydro-3-(4-methylphenyl)-8-(4-morpholinyl)-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (9b). Yield 65%. Colorless prisms. Mp 286 °C (from DMF); ν_{max} (KBr tablets) 3395, 3345, 2980, 2220, 1745, 1560, 1465, 1305, 855, 775, 705, 670 cm^{-1}. δ_H 7.27 (4H, m, H_{R1}), 7.23 (2H, s, NH_2), 6.55 (2H, s, NH_2), 3.86 (2H, s, 1-CH_2), 3.68 (8H, m, NR_2), 2.36 (3H, s, CH_3). δ_C 179.7 (2-CO), 161.7 (5-C), 158.8 (9a-C), 158.1 (6-C), 146.9 (8-C), 140.6 (3a-C), 138.7 (1-C_{R1}), 137.9 (4-C_{R1}), 129.7 (3,5-C_{R1}), 129.3 (2,6-C_{R1}), 114.4 (CN), 104.1 (5a-C), 89.7 (9b-C), 69.7 (9-C), 67.9 (OCH_2), 53.6 (NCH_2), 35.5 (1-C), 20.5 (CH_3). Found 63.5% C, 5.2% H, 23.8% N; $C_{22}H_{21}N_7O_2$ requires 63.6% C, 5.1% H, 23.6% N.

3.1.7. 5,6-Diamino-2,3-dihydro-3-(3,4-dimethoxyphenyl)-8-(4-morpholinyl)-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (9c). Yield 57%. Light-brown powder. Mp 201 °C (from EtOH); ν_{max} (KBr tablets) 3415, 3345, 2935, 2220, 1740, 1600, 1550, 1450, 1270, 1130, 1035, 820 cm^{-1}. δ_H 7.23 (2H, s, NH_2), 7.04 (1H, d, J=8.1 Hz, 5-H_{R1}), 6.98 (1H, d, J=1.8 Hz, 2-H_{R1}), 6.90 (1H, dd, J=8.1, 1.8 Hz, 6-H_{R1}), 6.57 (2H, s, NH_2), 3.85 (2H, s, 1-CH_2), 3.80 (3H, s, OCH_3), 3.75 (3H, s, OCH_3), 3.69 (8H, m, NR_2). δ_C 178.8 (2-CO), 158.8 (5-C), 157.9 (6-C), 156.0 (9a-C), 152.2 (3-C_{R1}), 152.0 (4-C_{R1}), 150.2 (8-C), 143.9 (3a-C), 130.3 (1-C_{R1}), 118.6 (6-C_{R1}), 115.2 (CN), 109.5 (2-C_{R1}), 107.7 (5-C_{R1}), 98.6 (5a-C), 93.4 (9b-C), 68.5 (9-C), 63.5 (OCH_2), 56.0 (OCH_3), 55.9 (OCH_3), 50.7 (NCH_2), 41.4 (1-C). Found: 59.6% C, 4.9% H, 21.1% N; $C_{23}H_{23}N_7O_4$ requires 59.9% C, 5.0% H, 21.3% N.

3.1.8. 5,6-Diamino-2,3-dihydro-3-[(4-methoxyphenyl)-methyl]-8-(4-morpholinyl)-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (9d). Yield 51%. Colorless needles. Mp 217 °C (from dioxane); ν_{max} (KBr tablets) 3425, 3320, 2940, 2200, 1730, 1605, 1570, 1420, 1355, 1305, 1285, 1215, 1000, 940, 865 cm^{-1}. δ_H 7.31 (4H, m,

NH_2, H_{R1}), 6.88 (2H, d, J=8.0 Hz, H_{R1}), 6.71 (2H, s, NH_2), 4.77 (2H, s, N3–CH_2), 3.76 (2H, s, 1-CH_2), 3.73, (3H, s, OCH_3), 3.69 (8H, m, NR_2). δ_C 179.3 (2-CO), 168.2 (9a-C), 160.3 (5-C), 159.2 (4-C_{R1}), 156.6 (6-C), 146.5 (3a-C), 146.1 (8-C), 130.8 (2,6-C_{R1}), 129.3 (1-C_{R1}), 116.1 (CN), 115.8 (3,5-C_{R1}), 103.1 (5a-C), 92.4 (9b-C), 67.9 (9-C), 64.3 (OCH_2), 55.3 (OCH_3), 55.1 (NCH_2), 43.9 (N3–CH_2) 36.4 (1-C). Found: 62.2% C, 5.1% H, 21.9% N; $C_{23}H_{23}N_7O_3$ requires 62.0% C, 5.2% H, 22.0% N.

3.1.9. 3-(3-Chlorophenyl)-5,6-diamino-2,3-dihydro-8-(4-morpholinyl)-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (9e). Yield 70%. Light-gray powder. Mp >300 °C (from DMF); ν_{max} (KBr tablets) 3420, 3300, 2915, 2220, 1740, 1610, 1490, 1470, 1280, 1170, 1120, 1050, 940, 790 cm^{-1}. δ_H 7.48 (2H, m, 4,6-H_{R1}), 7.42 (1H, s, 2-H_{R1}), 7.38 (1H, t, J=6.6 Hz, 5-H_{R1}), 7.11 (2H, s, NH_2), 6.49 (2H, s, NH_2), 3.86 (2H, s, 1-CH_2), 3.71 (8H, m, NR_2). δ_C 181.1 (2-CO), 162.3 (6-C), 159.7 (5-C), 158.6 (9a-C), 149.4 (8-C), 147.1 (3a-C), 137.7 (1-C_{R1}), 135.5 (3-C_{R1}), 130.0 (4-C_{R1}), 128.9 (6-C_{R1}), 127.5 (5-C_{R1}), 123.4 (2-C_{R1}), 115.5 (CN), 104.7 (5a-C), 94.7 (9b-C), 66.3 (9-C), 65.4 (OCH_2), 53.4 (NCH_2), 37.5 (1-C). Found: 57.7% C, 4.2% H, 8.3% Cl, 22.6% N; $C_{21}H_{18}ClN_7O_2$ requires 57.9% C, 4.2% H, 8.1% Cl, 22.5% N.

3.1.10. 5,6-Diamino-8-diethylamino-2,3-dihydro-2-oxo-3-[4-(*i*-propyl)phenyl]-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (10a). Yield 63%. White needles. Mp 255 °C (from dioxane); ν_{max} (KBr tablets) 3410, 3345, 2980, 2210, 1730, 1670, 1435, 1300, 1275, 1205, 1195, 1100, 1060, 800, 725 cm^{-1}. δ_H 7.37 (2H, d, J=8.0 Hz, H_{R1}), 7.32 (2H, d, J=8.0 Hz, H_{R1}), 7.11 (2H, s, NH_2), 6.53 (2H, s, NH_2), 3.92 (2H, s, 1-CH_2), 3.66 (4H, q, J=6.4 Hz, NR_2), 2.97 (1H, m, *i*-Pr), 1.27 (12H, m, NR_2, *i*-Pr). δ_C 178.7 (2-CO), 159.9 (6-C), 158.3 (5-C), 157.5 (9a-C), 146.6 (8-C), 144.6 (3a-C), 134.8 (1-C_{R1}), 133.5 (4-C_{R1}), 130.7 (3,5-C_{R1}), 126.4 (2,6-C_{R1}), 117.1 (CN), 104.2 (5a-C), 91.5 (9b-C), 68.7 (9-C), 44.6 (C_{NR2}), 36.3 (1-C), 35.8 (*i*-Pr), 21.9 (*i*-Pr), 14.1 (C_{NR2}). Found: 67.0% C, 6.6% H, 22.9% N; $C_{24}H_{27}N_7O$ requires 67.1% C, 6.3% H, 22.8% N.

3.1.11. 5,6-Diamino-8-diethylamino-2,3-dihydro-3-(4-methylphenyl)-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (10b). Yield 66%. Colorless plates. Mp 225 °C (from DMF); ν_{max} (KBr tablets) 3440, 3330, 2950, 2210, 1735, 1610, 1445, 1340, 1215, 1125, 810, 735, 705, 600 cm^{-1}. δ_H 7.28 (2H, d, J=8.0 Hz, H_{R1}), 7.24 (2H, d, J=8.0 Hz, H_{R1}), 7.07 (2H, s, NH_2), 6.47 (2H, s, NH_2), 3.89 (2H, s, 1-CH_2), 3.63 (4H, q, J=6.4 Hz, NR_2), 2.35 (3H, s, CH_3), 1.20 (6H, t, J=6.4 Hz, NR_2). δ_C 179.6 (2-CO), 164.5 (9a-C), 158.9 (6-C), 158.3 (5-C), 156.0 (8-C), 139.9 (3a-C), 136.1 (4-C_{R1}), 133.5 (1-C_{R1}), 128.7 (3,5-C_{R1}), 126.4 (2,6-C_{R1}), 119.1 (CN), 96.7 (5a-C), 89.1 (9b-C), 69.8 (9-C), 47.3 (C_{NR2}), 37.9 (1-C), 17.5 (CH_3), 9.5 (C_{NR2}). Found: 65.7% C, 5.9% H, 24.2% N; $C_{22}H_{23}N_7O$ requires 65.8% C, 5.8% H, 24.4% N.

3.1.12. 5,6-Diamino-8-diethylamino-2,3-dihydro-3-(3,4-dimethoxyphenyl)-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (10c). Yield 58%. Yellow powder. Mp 132 °C (from EtOH); ν_{max} (KBr tablets) 3450, 3335, 2930, 2210, 1750, 1630, 1475, 1240, 1175, 1070, 850 cm^{-1}. δ_H 7.08 (2H, s, NH_2), 7.02 (1H, dd, J=8.4, 1.6 Hz, 6-H_{R1}), 6.97 (1H, d, J=1.6 Hz, 2-H_{R1}), 6.89 (2H, d, J=8.4 Hz, 5-H_{R1}), 6.50 (2H, s, NH_2), 3.90 (2H, s, 1-CH_2), 3.79 (3H, s, OCH_3), 3.73 (3H, s, OCH_3), 3.62 (4H, q, J=6.0 Hz, NR_2), 1.19 (6H, t, J=6.0 Hz, NR_2). δ_C 179.5 (2-CO), 161.6 (9a-C), 158.6 (5-C), 157.8 (6-C), 157.5 (8-C), 156.8 (3-C_{R1}), 148.9 (4-C_{R1}), 144.8 (3a-C), 127.8 (1-C_{R1}), 118.7 (CN), 118.2 (6-C_{R1}), 115.7 (5-C_{R1}), 111.7 (2-C_{R1}), 98.1 (5a-C), 92.2 (9b-C), 70.8 (9-C), 58.7 (OCH_3), 55.7 (OCH_3), 41.9 (C_{NR2}), 36.3 (1-C), 13.7 (C_{NR2}). Found: 62.0% C, 5.9% H, 22.0% N; $C_{23}H_{25}N_7O_3$ requires 61.7% C, 5.6% H, 21.9% N.

3.1.13. 5,6-Diamino-8-diethylamino-2,3-dihydro-3-[(4-methoxyphenyl)methyl]-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (10d). Yield 60%. White powder. Mp 193 °C (from EtOH); ν_{max} (KBr tablets) 3410, 3330, 2970, 2210, 1730, 1605, 1585, 1450, 1320, 1305, 1250, 1215, 1070, 945, 890 cm^{-1}. δ_H 7.28 (2H, d, J=7.6 Hz, H_{R1}), 7.05 (2H, s, NH_2), 6.84 (2H, d, J=7.6 Hz, H_{R1}), 6.58 (2H, s, NH_2), 4.73 (2H, s, N3–CH_2), 3.76 (2H, s, 1-CH_2), 3.70 (3H, s, OCH_3), 3.61 (4H, q, J=6.0 Hz, NR_2), 1.18 (6H, t, J=6.0 Hz, NR_2). δ_C 177.1 (2-CO), 159.5 (6-C), 158.7 (4-C_{R1}), 158.2 (8-C), 158.1 (5-C), 157.4 (9a-C), 146.5 (3a-C), 129.5 (2,6-C_{R1}), 127.4 (1-C_{R1}), 116.5 (CN), 115.2 (3,5-C_{R1}), 99.1 (5a-C), 87.6 (9b-C), 68.4 (9-C), 59.1 (OCH_3), 46.1 (C_{NR2}), 43.7 (NCH_2), 37.1 (1-C), 13.6 (C_{NR2}). Found: 63.9% C, 6.0% H, 23.0% N; $C_{23}H_{25}N_7O_2$ requires 64.0% C, 5.8% H, 22.7% N.

3.1.14. 3-(4-Chlorophenyl)-5,6-diamino-8-diethylamino-2,3-dihydro-2-oxo-1*H*-pyrrolo[2,3-*c*]2,7-naphthyridine-9-carbonitrile (10f). Yield 69%. Yellow needles. Mp 242 °C (from DMF); ν_{max} (KBr tablets) 3405, 3300, 2955, 2220, 1750, 1665, 1445, 1385, 1345, 1130, 1050, 840 cm^{-1}. δ_H 7.55 (2H, d, J=8.4 Hz, H_{R1}), 7.45 (2H, d, J=8.4 Hz, H_{R1}), 7.11 (2H, s, NH_2), 6.52 (2H, s, NH_2), 3.91 (2H, s, 1-CH_2), 3.64 (4H, q, J=7.2 Hz, NR_2), 1.20 (6H, t, J=7.2 Hz, NR_2). δ_C 177.2 (2-CO), 167.6 (9a-C), 158.5 (5-C), 155.4 (6-C), 154.6 (8-C), 144.4 (3a-C), 135.1 (1-C_{R1}), 133.9 (4-C_{R1}), 127.1 (2,6-C_{R1}), 124.9 (3,5-C_{R1}), 116.8 (CN), 98.5 (5a-C), 91.3 (9b-C), 68.5 (9-C), 46.5 (C_{NR2}), 36.2 (1-C), 9.9 (C_{NR2}). Found: 59.9% C, 4.5% H, 23.2% N, 8.6% Cl; $C_{21}H_{20}ClN_7O$ requires 59.8% C, 4.8% H, 23.2% N, 8.4% Cl.

3.2. Pyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]2,7-naphthyridines 13a–d. General procedure

A solution of pyrrolonaphthyridine **8a**,**b**, **9e**, **10f** (2 mmol) in acetic acid anhydride (5 ml) was refluxed for 30 min. After cooling the precipitate formed was filtered, washed with water and recrystallized from DMF to yield derivatives **13a–d**.

3.2.1. 5-Methyl-9-oxo-2-(1-piperidinyl)-8-[4-(*i*-propyl)-phenyl]-6,8,9,10-tetrahydropyrimido[4,5,6-*ij*]pyrrolo-[2,3-*c*]2,7-naphthyridine-1-carbonitrile (13a). Yield 95%. Pale-yellow powder. Mp >300 °C (from DMF); ν_{max} (KBr tablets) 2980, 2955, 2890, 2205, 1750, 1670, 1640, 1600, 1530, 1450, 1325, 1205, 1160, 1120, 1040, 920, 840, 685 cm^{-1}. δ_H 12.78 (1H, br s, NH), 7.37 (2H, d, J=8.0 Hz, H_{R1}), 7.33 (2H, d, J=8.0 Hz, H_{R1}), 3.85 (2H, s, 10-CH_2),

3.72 (4H, m, NCH_2), 2.97 (1H, m, *i*-Pr), 2.31 (3H, s, 5-CH_3), 1.62 (6H, m, $CH_2CH_2CH_2$), 1.25 (6H, d, J=6.8 Hz, *i*-Pr). δ_C 169.2 (9-CO), 151.8 (5-C), 150.3 (6a-C), 147.7 (3a-C), 146.3 (2-C), 145.4 (7a-C), 131.5 (4-C_{R1}), 130.8 (1-C_{R1}), 127.6 (3,5-C_{R1}), 122.1 (2,6-C_{R1}), 117.7 (10b-C), 107.1 (CN), 96.8 (10c-C), 89.2 (10a-C), 65.1 (1-C), 53.4 (2,6-C_{NR2}), 33.1 (*i*-Pr), 26.2 (3.5-C_{NR2}), 26.1 (10-C), 24.5 (4-C_{NR2}), 16.3 (5-CH_3), 15.8 (*i*-Pr). Found: 69.4% C, 5.7% H, 21.0% N; $C_{27}H_{27}N_7O$ requires 69.7% C, 5.9% H, 21.1% N.

3.2.2. 5-Methyl-8-(4-methylphenyl)-9-oxo-2-(1-piperidinyl)-6,8,9,10-tetrahydropyrimido[4,5,6-*ij*]pyrrolo-[2,3-*c*]2,7-naphthyridine-1-carbonitrile (13b). Yield 99%. Yellow plates. Mp >300 °C (from DMF); ν_{max} (KBr tablets) 3300, 2955, 2875, 2210, 1725, 1645, 1590, 1535, 1455, 1330, 1215, 1170, 825 cm^{-1}. δ_H 12.84 (1H, br s, NH), 7.30 (4H, m, H_{R1}), 3.85 (2H, s, 10-CH_2), 3.72 (4H, m, NCH_2), 2.37 (3H, s, CH_3), 2.31 (3H, s, CH_3), 1.62 (6H, m, $CH_2CH_2CH_2$). δ_C 170.9 (9-CO), 153.5 (5-C), 151.1 (2-C), 150.2 (6a-C), 144.7 (3a-C), 137.8 (7a-C), 135.1 (4-C_{R1}), 134.6 (1-C_{R1}), 125.1 (2,6-C_{R1}), 124.4 (3,5-C_{R1}), 120.4 (10b-C), 108.7 (CN), 100.9 (10c-C), 94.5 (10a-C), 62.3 (1-C), 47.2 (2,6-C_{NR2}), 26.5 (10-C), 23.4 (3.5-C_{NR2}), 17.7 (CH_3), 17.6 (4-C_{NR2}), 9.9 (5-CH_3). Found: 68.8% C, 5.5% H, 22.3% N; $C_{25}H_{23}N_7O$ requires 68.6% C, 5.3% H, 22.4% N.

3.2.3. 8-(3-Chlorophenyl)-5-methyl-2-(4-morpholinyl)-9-oxo-6,8,9,10-tetrahydropyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]-2,7-naphthyridine-1-carbonitrile (13c). Yield 91%. Pale-green powder. Mp >300 °C (from DMF); ν_{max} (KBr tablets) 2975, 2220, 1745, 1585, 1475, 1400, 1305, 1270, 1195, 1125, 1055, 970, 820 cm^{-1}. δ_H 12.96 (1H, br s, NH), 7.59 (1H, s, 2-H_{R1}), 7.54 (2H, m, 4,6-H_{R1}), 7.47 (1H, t, J=7.2 Hz, 5-H_{R1}), 3.83 (2H, s, 10-CH_2), 3.70 (4H, m, OCH_2), 3.67 (4H, m, NCH_2), 2.33 (3H, s, CH_3). δ_C 172.6 (9-CO), 151.1 (5-C), 149.9 (3a-C), 148.6 (6a-C), 147.8 (2-C), 139.9 (3-C_{R1}), 138.3 (7a-C), 133.2 (1-C_{R1}), 125.9 (4-C_{R1}), 125.8 (10b-C), 125.4 (5-C_{R1}), 125.3 (2-C_{R1}), 123.4 (6-C_{R1}), 108.8 (CN), 96.8 (10c-C), 87.6 (10a-C), 67.8 (OCH_2), 64.3 (1-C), 46.6 (NCH_2), 26.9 (10-C), 18.5 (5-CH_3). Found: 60.0 C, 4.1% H, 7.9% Cl, 21.2% N; $C_{23}H_{18}ClN_7O_2$ requires 60.1% C, 4.0% H, 7.7% Cl, 21.3% N.

3.2.4. 8-(4-Chlorophenyl)-2-diethylamino-5-methyl-9-oxo-6,8,9,10-tetrahydropyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]-2,7-naphthyridine-1-carbonitrile (13d). Yield 94%. Yellow prisms. Mp >300 °C (from DMF); ν_{max} (KBr tablets) 2955, 2210, 1750, 1650, 1445, 1365, 1330, 1160, 1105, 1030, 840 cm^{-1}. δ_H 12.83 (1H, br s, NH), 7.57 (2H, d, J=8.8 Hz, H_{R1}), 7.48 (2H, d, J=8.8 Hz, H_{R1}), 3.90 (2H, s, 10-CH_2), 3.67 (4H, q, J=7.2 Hz, NR_2), 2.31 (3H, s, CH_3); 1.23 (6H, t, J=7.2 Hz, NR_2). δ_C 168.7 (9-CO), 156.5 (5-C), 151.1 (2-C), 146.5 (6a-C), 145.4 (3a-C), 141.5 (7a-C), 132.7 (1-C_{R1}), 129.1 (4-C_{R1}), 121.6 (3,5-C_{R1}), 119.7 (2,6-C_{R1}), 119.4 (10b-C), 107.5 (CN), 95.0 (10c-C), 92.8 (10a-C), 61.0 (1-C), 37.6 (C_{NR2}), 25.2 (10-C), 10.8 (5-CH_3), 2.7 (C_{NR2}). Found: 62.1% C, 4.3% H, 7.8% Cl, 22.0% N; $C_{23}H_{20}ClN_7O$ requires 62.0% C, 4.5% H, 8.0% Cl, 22.0% N.

3.3. Spiro{pyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]2,7-naphthyridine-5,1′-cyclohexanes} 14a–d. General procedure

A solution of pyrrolonaphthyridine **8a**,**b**, **9e**, **10f** (2 mmol) in cyclohexanone (5 ml) was heated at 100 °C for 1 h. After cooling water (10 ml) was added resulting in a dark oil separation. The liquid was decanted; the oil was dissolved in ethanol and then precipitated again by water as pale crystals, which were filtered and recrystallized from an appropriate solvent to give compounds **14a–d**.

3.3.1. 4,5,6,8,9,10-Hexahydro-9-oxo-2-(1-piperidinyl)-8-[4-(*i*-propyl)phenyl]-sprio{pyrimido[4,5,6-*ij*]pyrrolo-[2,3-*c*]2,7-naphthyridine-5,1′-cyclohexane}-1-carbonitrile (14a). Yield 68%. White powder. Mp 278 °C (from dioxane); ν_{max} (KBr tablets) 3300, 2965, 2890, 2205, 1725, 1650, 1535, 1495, 1295, 1200, 1155, 1065, 875, 760 cm^{-1}. δ_H 8.06 (1H, s, NH), 7.77 (1H, s, NH), 7.34 (2H, d, J=8.0 Hz, H_{R1}), 7.27 (2H, d, J=8.0 Hz, H_{R1}), 3.81 (2H, s, 10-CH_2), 3.69 (4H, m, NCH_2), 2.94 (1H, m, *i*-Pr), 1.71 (4H, m, 2′,6′-CH_2), 1.60 (10H, m, NR_2, 3′,5′-CH_2), 1.30 (2H, m, 4′-CH_2), 1.22 (6H, d, J=6.8 Hz, *i*-Pr). δ_C 177.1 (9-CO), 160.6 (10b-C), 158.4 (3a-C), 156.6 (2-C), 156.4 (6a-C), 143.4 (7a-C), 136.7 (4-C_{R1}), 135.6 (1-C_{R1}), 127.6 (3,5-C_{R1}), 124.4 (2,6-C_{R1}), 117.6 (CN), 98.2 (10c-C), 88.3 (10a-C), 73.2 (5-C), 69.7 (1-C), 50.1 (2,6-C_{NR2}), 39.5 (2′,6′-C), 36.6 (10-C), 36.5 (*i*-Pr), 23.9 (4′-C), 23.6 (3,5-C_{NR2}), 20.5 (*i*-Pr), 19.9 (3′,5′-C), 19.7 (4-C_{NR2}). Found: 71.3% C, 6.9% H, 18.7% N; $C_{31}H_{35}N_7O$ requires 71.4% C, 6.8% H, 18.8% N.

3.3.2. 4,5,6,8,9,10-Hexahydro-8-(4-methylphenyl)-9-oxo-2-(1-piperidinyl)-sprio{pyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]-2,7-naphthyridine-5,1′-cyclohexane}-1-carbonitrile (14b). Yield 76%. Pale-pink powder. Mp >300 °C (from DMF–H_2O mixture); ν_{max} (KBr tablets) 3300, 2955, 2875, 2205, 1725, 1620, 1520, 1465, 1335, 1205, 1160, 1035, 810, 725 cm^{-1}. δ_H 8.06 (1H, s, NH), 7.77 (1H, s, NH), 7.28 (2H, d, J=8.8 Hz, H_{R1}), 7.22 (2H, d, J=8.8 Hz, H_{R1}), 3.80 (2H, s, 10-CH_2), 3.68 (4H, m, NCH_2), 2.35 (3H, s, CH_3), 1.70 (4H, m, 2′,6′-CH_2), 1.60 (10H, m, NR_2, 3′,5′-CH_2), 1.29 (2H, m, 4′-CH_2). δ_C 174.8 (9-CO), 164.2 (10b-C), 159.8 (2-C), 156.2 (6a-C), 155.6 (3a-C), 141.7 (7a-C), 137.7 (4-C_{R1}), 132.0 (1-C_{R1}), 129.9 (3,5-C_{R1}), 128.4 (2,6-C_{R1}), 121.2 (CN), 94.0 (10c-C), 90.7 (10a-C), 68.8 (5-C), 67.9 (1-C), 49.4 (2,6-C_{NR2}), 37.3 (2′,6′-C), 34.7 (10-C), 26.4 (3,5-C_{NR2}), 25.1 (4-C_{NR2}), 24.7 (4′-C), 21.3 (CH_3), 20.9 (3′,5′-C). Found: 70.7% C, 6.2% H, 19.9% N; $C_{29}H_{31}N_7O$ requires 70.6% C, 6.3% H, 19.9% N.

3.3.3. 8-(3-Chlorophenyl)-4,5,6,8,9,10-hexahydro-2-(4-morpholinyl)-9-oxosprio{pyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]-2,7-naphthyridine-5,1′-cyclohexane}-1-carbonitrile (14c). Yield 76%. White powder. Mp 288 °C (from DMF–H_2O mixture); ν_{max} (KBr tablets) 3420, 3335, 2975, 2885, 2210, 1750, 1625, 1495, 1450, 1335, 1285, 1190, 1120, 1045, 970, 800 cm^{-1}. δ_H 8.21 (1H, s, NH), 7.88 (1H, s, NH), 7.53 (2H, m, 2,5-H_{R1}), 7.46 (1H, d, J=7.2 Hz, 4-H_{R1}), 7.39 (1H, d, J=7.6 Hz, 6-H_{R1}), 3.82 (2H, s, 10-CH_2), 3.70 (8H, m, NR_2), 1.72 (4H, m, 2′,6′-CH_2), 1.58 (4H, m, 3′,5′-CH_2), 1.31 (2H, m, 4′-CH_2). δ_C 179.9 (9-CO), 160.6 (6a-C), 160.4 (10b-C), 156.6 (2-C), 153.5 (3a-C), 138.4 (7a-C), 137.7 (3-C_{R1}), 131.5 (1-C_{R1}), 126.3 (4-C_{R1}), 124.7 (5-C_{R1}), 123.6 (2-C_{R1}), 123.4 (6-C_{R1}), 118.8 (CN), 94.2 (10c-C), 92.2 (10a-C), 67.5 (1-C), 67.4 (5-C), 61.9 (OCH_2), 49.2 (NCH_2), 40.4 (2′,6′-C), 37.2 (10-C), 25.7 (3′,5′-C), 18.4 (4′-C). Found: 63.0% C, 5.0% H, 6.7% Cl, 18.9% N; $C_{27}H_{26}ClN_7O_2$ requires 62.9% C, 5.1% H, 6.9% Cl, 19.0% N.

3.3.4. 8-(4-Chlorophenyl)-2-diethylamino-4,5,6,8,9,10-hexahydro-9-oxosprio{pyrimido[4,5,6-*ij*]pyrrolo[2,3-*c*]-2,7-naphthyridine-5,1′-cyclohexane}-1-carbonitrile (14d). Yield 71%. White powder. Mp 164 °C (from DMF–EtOH mixture); ν_{max} (KBr tablets) 3340, 2955, 2210, 1745, 1625, 1515, 1445, 1335, 1105, 810, 715 cm^{-1}. δ_H 7.53 (1H, s, NH), 7.48 (3H, m, NH, H_{R1}), 7.42 (2H, d, J=8.4 Hz, H_{R1}), 3.86 (2H, s, 10-CH_2), 3.70 (4H, q, J=7.2 Hz, NR_2), 1.77 (4H, m, 2′,6′-CH_2), 1.62 (4H, m, 3′,5′-CH_2), 1.40 (2H, m, 4′-CH_2), 1.27 (6H, t, J=7.2 Hz, NR_2). δ_C 174.9 (9-CO), 165.2 (10b-C), 158.1 (3a-C), 155.6 (6a-C), 151.5 (2-C), 145.2 (7a-C), 137.5 (4-C_{R1}), 133.3 (1-C_{R1}), 126.7 (2,6-C_{R1}), 124.4 (3,5-C_{R1}), 116.8 (CN), 95.5 (10c-C), 87.4 (10a-C), 70.1 (5-C), 69.9 (1-C), 40.6 (C_{NR2}), 39.7 (2′,6′-C), 38.8 (10-C), 25.3 (4′-C), 21.1 (3′,5′-C), 10.5(C_{NR2}). Found: 64.8% C, 5.7% H, 7.2% Cl, 19.5% N; $C_{27}H_{28}ClN_7O$ requires 64.6% C, 5.6% H, 7.1% Cl, 19.5% N.

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