

Is BA (6-Benzyladenine) BAP (6-Benzylaminopurine)?

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ABSTRACT

Yes it is. This is the answer to the title. Why the question was asked is because plant scientists appear to be almost equally divided in their use of the abbreviation BA and BAP to describe the exact same cytokinin, 6-benzyladenine or 6-benzylamino purine, a synthetic compound (the natural form being Cytokinin B) commonly used in plant tissue culture. This short paper seeks to provide some clarification and to highlight the issues and disputes regarding the nomenclature of this (and other) cytokinins. A short survey of 38 countries indicates that BAP is used in 63% many more countries than in BA. Interestingly, in Japan at least, Wako and Sigma-Aldrich list the purchasable product as BAP, directly influencing the choice by scientists.

Keywords: cytokinins

Abbreviations: BA, 6-benzyladenine; BAP, 6-benzylaminopurine

Assessing the BA vs BAP conundrum

Cytokinins are N⁶-substituted adenine derivatives and a class of plant hormones involved in plant growth and development (D'Agostino and Kieber 1999).

When I recently asked Professor John Finer, Department of Horticulture and Crop Science, The Ohio State University, and Editor-in-Chief of *In Vitro Cellular and Developmental Biology – Plant*, about why there are two names for the same cytokinin, BA (6-benzyladenine) and BAP (6-benzylaminopurine), the response I received was “I believe that BA and BAP are the same. I prefer to use BA but it is OK to use BAP. Whichever you use, it is best to be consistent and use the same abbreviation and word throughout. There are other chemicals that can be named differently but are the same (glucose and dextrose come to mind). For IV[CDB]-P, you can use either BAP or BA but I prefer BA.” This response suggested that the choice was personal rather than based on a scientific decision, and I decided to investigate further, also because of my own personal bias in the choice of BA over BAP. Although *IVCDB – Plant* (Springer) appears to be flexible about the nomenclature and abbreviation used, another Springer journal, *Plant, Cell, Tissue and Organ Culture* (PCTOC) insists on the use of BA, and never BAP, simply because of the personal preference of Editor-in-Chief of PCTOC, Prof. Schuyler S. Korban. In response to my query, “I would like to know what is PCTOC's official position on the use of BA vs BAP in manuscripts submitted to PCTOC. Although my understanding that they are the same cytokinin, the use appears to be culturally determined, or enforced by specific journals. So, I would like to know your [i.e., the journal's] position regarding this small point. For example, I always personally prefer to use BA, based on plant biochemists' advice (Malito *et al.* 2004), but, for example, if another uses BAP in their text, would it be correct to refer to it as BA, either because of personal choice, or because the choice is imposed (by editors or journals)?”, Prof. Korban provided an official response: “As both BA (6-benzyladenine) and BAP (benzylaminopurine) are the same cytokinin, yes you can switch their use based on the journal's preference even if it is originally reported as BAP in another publication. Like you, I personally prefer the use of BA, and that's the reason authors publishing in PCTOC are requested to use BA.” Prof. Joseph Kieber of the University of North Carolina

puts it simply “I prefer the simple term BA, but there is no agreed upon convention.”

These discrepancies within the world of plant science publishing can cause confusion, particularly among novice plant tissue culture scientists, and thus I decided to investigate further.

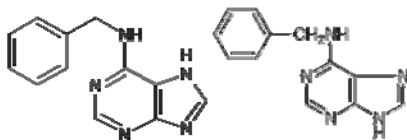
The three questions I wanted to answer were:

- Are these two compounds in fact the same and if yes then why are they given different names?
- Why are plant biologists using two terms so loosely throughout the literature?
- Is the difference in use culturally or geographically based?

From my search of the literature in academic texts, I found the best and most comprehensive, and most recent explanation to have been provided by Kamínek *et al.* (2000). These authors also alluded to this lack of uniformity in cytokinin nomenclature and corresponding abbreviations. They claimed that “It is difficult to unify the cytokinin nomenclature because of the relatively complicated systematic names, which force plant physiologists to use semi-systematic as well as trivial names. However, it may be possible to reach a consensus about cytokinin abbreviations.” Crouch *et al.* (1993) in fact had suggested almost 20 abbreviations for 6-benzylaminopurine. Even though the IUPAC-IUB (Joint Commission on Biochemical Nomenclature (International Union of Pure and Applied Chemistry and International Union of Biochemistry and Molecular Biology)) Commission on Biochemical Nomenclature in 1967 and 1970 suggested the names and abbreviations for nucleic acids and their components, including cytokinins (see actual IUPAC name for BA in **Table 1**), the reason why plant scientists have not adopted these is, according to Kamínek *et al.*, “The most likely reason for this has been the ambiguous meaning and complicated typing due to the use of three-letter symbols for adenine and adenosine, which serve as a basis for construction of cytokinin abbreviations using superscripts for locants and both hyphens and apostrophes for denotation of nucleotides.” However, both Crouch *et al.* (1993) and Letham and Palni (1983) decided that the best abbreviation for 6-benzylaminopurine was BA, adding even more confusion to the situation, as one would have expected the corresponding abbreviation of 6-benzylaminopurine to be BAP! Kamínek *et al.* (2000) re-adjust the abbreviation as BA for 6-benzyladenine and this appears to

Table 1 Definition of benzyladenine as per Wood (2012)

Status	none
IUPAC	<i>N</i> -benzyladenine or <i>N</i> -benzyl-7 <i>H</i> -purin-6-amine
CAS	<i>N</i> -(phenylmethyl)-1 <i>H</i> -purin-6-amine
Formula	C ₁₂ H ₁₁ N ₅
Notes	There is no ISO common name for this substance; the name “benzyladenine” has been used in the literature but it has no official status. The chemical name “6-benzylaminopurine” is approved as a common name in China, but has 2 entries in GB 4839-2009 <i>Chinese common names for pesticides</i> with different Chinese names, “苄腺嘌呤” and “苄氨基嘌呤”.

Structure

Benzyladenine (there is no entry for benzylaminopurine)
 Chinese: 苄腺嘌呤; French: benzyl adénine (n.f.); Russian: бензиладенин

Table 2 Additional (select) information of interest on benzyladenine, as listed by Herts (2011).

CAS RN	1214-39-7
EC number	214-927-5
CIPAC number	8029
US EPA chemical code	116901
SMILES	c12c(NCec3ccccc3)ncnc1[nH]2
International Chemical Identifier (InChI)	InChI=1/C12H11N5/c1-2-4-9(5-3-1)6-13-11-10-12(15-7-14-10)17-8-16-11/h1-5,7-8H,6H2,(H2,13,14,15,16,17)
Molecular mass (g mol ⁻¹)	225.25
IUPAC Name	<i>N</i> -(phenylmethyl)-1 <i>H</i> -purin-6-amine
CAS Name	6-benzylaminopurine

be the latest update on the use of cytokine nomenclature in plant science. Incidentally, the recommended abbreviation by Kamínek *et al.* (2000) for zeatin is Z and not Zea while that for kinetin is Kin and not KIN.

Alan Wood, a biochemist, characterizes BA in **Table 1**.

To add to the confusion, chemical companies, such as Neo Technology Ltd. Or Chem-online.org in China, refer to it as 6-BA while others such as Research Organics (USA) refer to it as BAP. Herts in the UK advances the latest information as indicated in **Table 2** (select fields only). What is fascinating is that Wood in **Table 1** lists the CAS and IUPAC names differently to the same names as Herts lists them (**Table 2**). The US-NIST (2011) provides a long list of alternative names to benzyladenine, but does not advise which abbreviation to use: 1*H*-purin-6-amine, *N*-(phenylmethyl)-; adenine, *N*-benzyl-; BA (growth stimulator); N6-benzyladenine; *N*-benzyladenine; SD 4901; SQ 4609; 6-(benzylamino)purine; 6-benzyladenine; BA; BA (growth stimulant); BAP; BAP (growth stimulant); N6-benzylaminopurine; *N*-(phenylmethyl)-1*H*-purin-6-amine; Verdan senescence inhibitor; ABG 3034; 6-BA; 6-BAP; benzylaminopurine; 6-(*N*-benzylamino)purine; 9*H*-purine, 6-[(phenylmethyl)amino]-; 9*H*-purin-6-amine, *N*-(phenylmethyl)-; cytokinin B; NSC 40818; Pro-Shear; *N*-benzyl-9*H*-purin-6-amine; 3458-19-3; 124786-41-0; benzyl(purin-6-yl)amine. Environmentalchemistry.com (2012) lists 32 synonyms for benzyladenine (commercial names excluded; see **Appendix**).

These cases would suggest that perhaps the commercial source from which scientists purchased BA/BAP would tend to use the name as recommended by the company rather than the name suggested by the literature or by the journal. To test this hypothesis, the latest (2012) product catalogue of the three largest chemical (general) companies in Japan, Wako, Sigma-Aldrich and Nacalai Tesque, were scrutinized. Very surprisingly, even though Wako and Sigma-Aldrich both listed BA and BAP, the product could only be purchased as BAP. In the case of Nacalai Tesque, both BA and BAP were listed, but BA was confusingly

listed as benzyl kinetin and absolutely no information about each was listed, so most likely, scientists would select the cheaper option in their catalogue, BAP (about 30% cheaper than BA). This clearly “biased” listing of product nomenclature would surely influence the choice that a scientist would use in their scientific manuscripts. It will be interesting to learn how similar catalogues list BA and BAP around the world.

To further confound the issue, a search on Elsevier’s sciencedirect.com reveals (number of searches up to November 2012) some interesting trends, after a crude search (**Table 3**): This in itself is a fascinating result because it indicates that both terms are being used in almost equal proportions (with a 2.5-5.1% margin or difference). A further search on the same data-base reveals other interesting facts, after cross-searching the same four key words or key word combinations with a random selection of country names around the world (**Table 3**). This country by country analysis was done since I had noticed (or felt) that scientists of some countries were using BA more than BAP, and *vice versa*, particularly in tissue culture studies, and I thus wanted to assess if there was any trend. Although the analysis is not an extremely profound one, it does show some interesting facts: the USA uses both terms the most, suggesting a higher level of tissue culture work or work more generally in science on this cytokinin. How can one interpret the numbers in **Table 3**? Let’s take two examples, to better exemplify. **Table 3** shows that scientists in Spain use BAP 42.5% more than BA while scientists in Brazil use BAP 37.0% less than BA. If we observe the statistics of these countries, we can clearly conclude that the use of BA vs BAP is clearly cultural (or geographical to be more precise) and that BAP is used in 63% many more countries than in BA (although only 38/195 countries were examined). Although there does not seem to be a trend on a continental basis e.g. East EU or West EU, South America, or Africa. Of very particular relevance is South Africa and Norway, which show an extreme bias towards the preferred use of BAP and Argentina which shows a strong bias towards the use of BA. Hungarian scientists appear to be equally split in their use of BA and BAP.

Although I could not answer the question as to what influences a scientist’s choice of the use of BA or BAP, I could at least confirm that they are one and the same cytokinin, synthetic (USDA-TAP 2004) (unlike natural cytokinins kinetin and zeatin), and equivalent to the natural Cytokinin B. There is a strong country-by-country use of either term (**Table 3**), and this might be influenced by the abbreviation given by different chemical companies that sell this cytokinin.

ACKNOWLEDGEMENTS

I wish to thank Dr. Judit Dobránszki (Research Institute of Nyíregyháza, Research and Innovation Centre, Centre of Agricultural Sciences and Engineering, University of Debrecen, Hungary), Prof. Guzel Kudoyarova (Institute of Biology, Ufa Research Center, Russian Academy of Sciences, Russia), Prof. Schuyler S. Korban (University of Illinois at Urbana-Champaign, Urbana, IL, USA), and Prof. Joseph Kieber (Department of Biology, University of North Carolina, NC, USA) for input, feed-back and valuable discussion.

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Table 3 Number of hits (descending order) following a search for benzyladenine and benzylaminopurine on Elsevier's Scencedirect.com. Countries that use BA more than BAP are highlighted in grey.

Key words	Benzyladenine	Benzyladenine + BA	Benzylaminopurine	Benzylaminopurine + BAP*
	2378	1288	2443	1222
USA		445		479 ↑ 7.6%
Japan		278		324 ↑ 16.5%
India		238		192 ↓ 19.3%
Germany		210		173 ↓ 17.6%
Netherlands		191		231 ↑ 20.9%
France		178		112 ↓ 37.1%
China		122		160 ↑ 31.1%
Italy		117		105 ↓ 10.3%
Canada		113		146 ↑ 29.2%
Australia		107		99 ↓ 7.5%
Spain		73		104 ↑ 42.5%
Switzerland		62		68 ↑ 9.7%
Belgium		62		39 ↓ 37.1%
Brazil		54		34 ↓ 37.0%
Israel		50		68 ↑ 36.0%
Argentina		43		22 ↓ 48.8%
Mexico		40		48 ↑ 20.0%
South Africa		38		85 ↑ 123.7%
Norway		38		73 ↑ 92.1%
New Zealand		37		57 ↑ 54.1%
Poland		37		26 ↓ 29.7%
Russia		27		38 ↑ 54.1%
Finland		26		22 ↓ 15.4%
Austria		23		17 ↓ 26.1%
Portugal		20		34 ↑ 70.0%
Nigeria		19		21 ↑ 10.5%
United Kingdom		16		24 ↑ 50.0%
Hungary		16		16 No difference
Pakistan		16		15 ↓ 6.3%
Egypt		13		16 ↑ 23.1%
Tunisia		12		3 ↓ 75.0%
Kenya		11		13 ↑ 18.2%
Colombia		10		15 ↑ 50.0%
Serbia		3		4 NA
Croatia		1		6 NA
Jamaica		1		3 NA

↑% or ↓% indicates the percentage increase or decrease (absolute values), respectively, of the use of BAP over BA.

NA = not analysed since one count difference is the equivalent of a 10% difference, which would likely strongly skew the result and interpretation.

Disclaimer: Indeed this is a coarse interpretation, but an interesting one nonetheless. The trend may be different on data-bases held by different publishers or different search engines and are not a conclusive perspective of what the trends might actually be.

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<http://www.alanwood.net/pesticides/benzyladenine.html>

Appendix: 32 synonyms for benzyladenine as listed by Environmentalchemistry.com (2012)

- 1H-purin-6-amine, N-(phenylmethyl)-
- 6-(Benzylamino) purine
- 6-(N-Benzylamino) purine
- 6-BA
- 6-BAP
- 6-Benzyladenine
- 6-Benzylaminopurine
- Adenine, N(sup 6)-benzyl-
- Adenine, N-benzyl-
- Aminopurine, 6-benzyl
- BA (growth stimulant)
- BaP
- BAP (growth stimulant)
- Benzyl(purin-6-yl) amine
- Benzyladenine
- Benzylaminopurine
- C11263
- CAS-1214-39-7
- CBDivE_001815
- Cytokinin B
- EMU
- N(6)-Benzylaminopurine
- N(sup 6)-(Benzylamino) purine
- N(sup 6)-Benzyladenine
- N-(Phenylmethyl)-1H-purin-6-amine
- N-Benzyl-9H-purin-6-amine
- N-Benzyladenine
- N6-Benzyladenine
- NCGC00016571-01
- SD 4901
- SQ 4609