

Identification of *Astragalus* Medicines Using Scar Markers

TSU-HWIE LIU*, HONG-MOU LIN AND REY-YUH WU

Development Center for Biotechnology, Taipei, Taiwan (R.O.C.)

(Received: February 12, 2007; Accepted: April 1, 2008)

ABSTRACT

Astragalus radix is a well-known herbal material in traditional Chinese medicine. *Astragalus membranaceus* and *A. membranaceus* var. *mongholicus* are known as the authentic origins of *Astragalus* medicines whereas *Hedysarum polybotrys* is a common adulterant of *Astragalus radix* in Taiwan. Random amplified polymorphic DNA (RAPD) primers were used to screen the polymorphic fragments. Among them, OPB-2 and OPC-14 directed the amplification of 3 specific fragments A1 (1.3 Kb), A2 (0.6 Kb) and H1 (0.8 Kb) from *A. membranaceus*, *A. membranaceus* var. *mongholicus* and *H. polybotrys* respectively, which were further converted to sequence characterized amplified region (SCAR) markers. Primer pairs HG3 and HG4 derived from A1, HG7 and HG8 from A2, and RC3 and RC4 from H3, were successfully employed on the authentication of *Astragalus* medicines and *H. polybotrys*.

Key words: *Astragalus*, authentication, polymorphism

INTRODUCTION

Astragalus Radix, also named as Huang Qi, is a well-known basic drug in traditional Chinese medicine. It has been formulated with other herbs and used as tonics for hundreds of years. In modern Chinese medicine, it is widely used as an immune-modulator or antioxidant in treating various chronic diseases such as cancer or cardiovascular diseases. The botanical origin of *Astragalus Radix* in Pharmacopoeia of China is the dried root of *Astragalus membranaceus* (Fisch.) Bge. and *A. membranaceus* (Fisch.) Bge. var. *mongholicus* (Bge.) Hsiao⁽¹⁾. However, there are many other species traded as *Astragalus Radix*; among them, *Hedysarum polybotrys* Hand.-Mazz. is the most common adulterant in Taiwan. Tung, *et al.*⁽²⁾ reported that over 85% of *Astragalus Radix* sold in the local markets were *H. polybotrys*. In addition to minor anatomical differences, the *Astragalus Radix* contains stone cells but no calcium oxalate crystals in root⁽³⁾ apart from *H. polybotrys*. Both *Astragalus Radix* and *Hedysarum Radix* own similar features, which make identification difficult.

The molecular markers in Chinese medicinal materials have been developed to identify many plant and animal species⁽⁴⁾. Polymorphic bands of *Astragalus radix* identified by random amplified polymorphic DNA (RAPD) method were described by Cheng, *et al.*⁽⁵⁾ and Na, *et al.*⁽⁶⁾. The disadvantage of this technique is poor fidelity since DNA quality plays a key role for the outcome of polymorphic bands⁽⁷⁾. The DNA extracted

from dried herbal materials is usually damaged and contaminated with proteins, polysaccharides and secondary metabolites, which might affect the reliability of the RAPD results greatly. To improve the reproducibility of RAPD markers, the polymorphic bands generated from RAPD can be converted to the sequence characterized amplified regions (SCAR)⁽⁸⁾, which is more specific than RAPD. It is reported that SCARs have several advantages over RAPD markers: (1) by using longer and sequence-specific PCR primers, SCARs improve the reproducibility of band polymorphism; (2) as the annealing temperatures are more stringent for SCARs than for RAPDs, only specific locus was detected by using each set of SCAR primers⁽⁹⁾. SCAR markers have been successfully developed to identify several Chinese medicinal materials, including *Panax* species⁽¹⁰⁾, *Crocodilian* species⁽¹¹⁾ and snakes⁽¹²⁾. In this study, we demonstrated that three species-specific RAPD bands obtained by cloning and sequencing were converted to SCAR markers of *A. membranaceus*, *A. membranaceus* var. *mongholicus* and *H. polybotrys* for their authentication.

MATERIALS AND METHODS

I. Plant Materials

Dried roots of *Astragalus membranaceus* (Fisch.) Bge., *A. membranaceus* (Fisch.) Bge. var. *mongholicus* Hsiao and *Hedysarum polybotrys* Hand-Mazz. were collected from Ji-Lin, Gan-Su and Shan-Xi provinces, China, respectively. Two sliced-root products of

* Author for correspondence. Tel: +886-2-2695-6933 ext. 1649; Fax: 886-2-2692-3031; E-mail: annieliu@mail.dcb.org.tw

Astragalus radix for fidelity test of SCAR primers were purchased from local stores. All samples were identified according to their anatomical characteristics^(1,3). Voucher specimens were deposited in the Development Center for Biotechnology, Taipei, Taiwan. Seeds of *A. sprunerii*, *A. obscurus*, and *A. garbancillo* were gifts from the Millennium Seed Bank Project of the Kew Garden, UK. All seeds were surface sterilized and aseptically germinated on semi-solid MS medium⁽¹³⁾ as described by Smith⁽¹⁴⁾. Three-month old micro-propagated plantlets were frozen with liquid nitrogen for further DNA extraction.

II. DNA Extraction

Dried roots of all samples were washed in tap-water and the outer skin was removed to avoid surface contamination. After being air dried, the samples were frozen with liquid nitrogen and ground into powder. Genomic DNA was extracted from the sample using DNeasy Plant Mini Kit (QIAGEN, Germany) by following the manufacturer's instructions. The DNA pellet was rinsed with 70% ethanol and resuspended in 50 μ L TE buffer and stored at -20°C.

III. RAPD Analysis

One hundred RAPD primers (Operon Technologies, CA, USA) were initially screened to detect species-specific markers. The PCR reaction mix (50 μ L) consisted of 100 ng of genomic DNA, 150 ng of RAPD primer, 1X PCR buffer, 1.5 mM MgCl₂, 250 μ M of each dNTPs and 2.5 U of *Taq* polymerase (Bertec, Taiwan). Reaction took place in a TaKaRa TP600 thermal cycler (Japan) by the following program: 5 min at 95°C, followed by 30 amplification cycles of 95°C for 30 sec, 48°C for 30 sec, and 72°C for 1 min, and finally 10 min at 72°C for elongation. The PCR products were resolved by electrophoresis on 1.5% agarose (Sigma, USA) gel and in TAE buffer.

IV. Cloning and Sequence of RAPD Products

Three specific RAPD markers: A1 derived from the primer OPB-2 (5'-TGATCCCTGG-3') for *A. membranaceus* var. *mongholicus*; A2 and H1 derived from the primer OPC-14 (5'-TGCGTGCTTG-3') for *A. membranaceus* and *H. polybotrys*, were excised from the agarose gel and the DNA was purified using QIAquick Gel Extraction Kit (QIAGEN, Germany). The eluted fragments were ligated into pGEM T Easy Vector (Promega, USA), transformed into *Escherichia coli* strain DH5 α and sequenced by ABI 3730 automated DNA sequencer (Applied Biosystems, USA).

V. SCAR Analysis

SCAR was amplified in a 50 μ L PCR reaction mix consisting of 100 ng of genomic DNA, 150 ng of RAPD

primers, 1X PCR buffer, 1.5 mM MgCl₂, 250 μ M of each dNTPs and 2.5 U of *Taq* polymerase (Bertec, Taiwan). The cycling profile for *A. membranaceus* was: 5 min at 95°C, followed by 25 amplification cycles of 95°C for 30 sec, 58°C for 30 sec, and 72°C for 30 sec, and finally 7 min at 72°C for elongation. The cycling profile for *A. membranaceus* var. *mongholicus* and *H. polybotrys* was: 5 min at 95°C, followed by 25 amplification cycles of 95°C for 30 sec, 64°C for 30 sec, and 72°C for 50 sec, and finally 10 min at 72°C for elongation.

RESULTS AND DISCUSSION

I. Identification of Specific RAPD Markers

RAPD method was performed in search for DNA polymorphic markers. Polymorphic profiles of *A. membranaceus* var. *mongholicus*, *A. membranaceus* and *H. polybotrys* were screened from the 100 RAPD primers (OPA1-20, OPB1-20, OPC1-20, OPD1-20, and OPE1-20). To increase the stringency between primers and genomic DNA, the annealing temperature was increased to 48°C which was higher than the normal condition and less polymorphic bands could be generated.

Table 1. Primer sequences used in the RAPD and SCAR analyses

Primer	Sequence
OPB-2	5'-TGATCCCTGG-3'
HG3	5'-CTATTAAAGACACATTCCGGG-3'
HG4	5'-AACCGCAACGTCGAATCACC-3'
OPC-14	5'-TGCGTGCTTG-3'
HG7	5'-ACTCGCGCAAGTTGGCTCCG-3'
HG8	5'-GTTGTTATGCTCCAGCGGGT-3'
RC3	5'-GTGCTTGGGCCAACATGGCT-3'
RC4	5'-GGGATGTCCGGGGAGAGTTA-3'

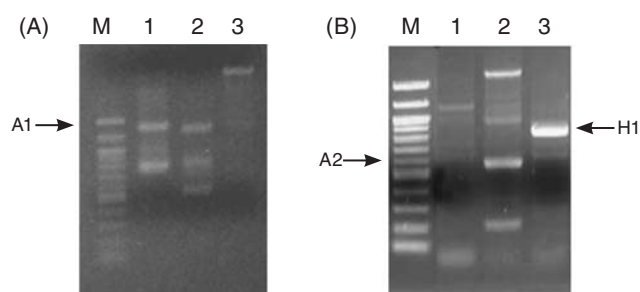


Figure 1. RAPD analysis of (A) OPB-2 primer; (B) OPC-14 primer. The arrows indicate the species-specific bands A1 (1.3 Kb), A2 (0.6 Kb) and H1 (0.8 Kb). Lane 1: *A. membranaceus* var. *mongholicus*; Lane 2: *A. membranaceus*; Lane 3: *H. polybotrys*; M: 100 bp molecular weight marker.

```

1  TCGCATGCTC  CCGGCCGCCA  TGGCGGCCGC  GGGAAATCGA  TTGGATCCCT  GGTCGGTGGC  60
61  TATGGA AAAA  CATTGTGTGG  GAGCGGTCAA  CCGCTTAAT  GGATCTCAAA  TACCTCAGAA  120
121  GGATTAGTCT  CCACAGTCCG  CGTGGAGGAT  ACCTTGGTTT  ACCCAAAAAA  AAAAAGTTTT  180
181  GGTTTCAGGA  GGTGGAATCA  CATTATAGTC  ACTTGGTCT  GTAAATATGT  GAGGTGTTCT  240
241  CATTTTAGTC  CTTGAATGCA  TCAAAATTCA  AAAAATGTT  TCAAAATGTT  TGTGTGTTCT  300
301  CAGTTTGGTT  CTCAAATGGG  TCTTATATTA  GTGGTCTTTG  TCCTCAGATG  TGCCTTCTAT  360
361  AAGTCATTTT  GGTCACTAGA  ATACTATTAA  AGACAGATTC  GGGAAATATT  TTGAAATTTG  420
421  AAGACATTCA  GGGACTATAA  TGATAAGGCC  TGACAGATTT  AAAGATCAAA  ATGACTATTG  480
481  AACCTATTTT  TAGTCACACT  TAAGTTGTCA  TTGTCTTTTT  ATGAAGTAAT  GATGGTGTGG  540
541  TTTACAAAAC  AAGTGGATAG  TAACTGCCCT  TTTTGGTATT  TTCATTCTTT  GGAGGTATGA  600
601  TGCAGAAATC  GTATGGTTTG  CAGGCAAGTC  CGTCCCAATC  ACTTTGGAGG  CCTGTGTCAA  660
661  GTTTTAAAAA  TTGGGCCATT  AATATACTTT  TATTGAATGA  ATCAACAAAA  CCACCTTTAA  720
721  CTACTTTATT  TAAATTTTAA  ATAACATCTC  AATACAACTT  TAAACTTAAT  ATACTAATTT  780
781  TCAAAACGATG  AATTGACAGG  GGCAGAGCTT  GGGATAGTTT  TTCAAACTGT  AGTTGAACCG  840
841  CATGACCAAT  TACTCGGTCT  AGATTAAAAA  ATTCCCAATC  TTTTAGGACC  TATAAATTTT  900
901  ATACATGTTA  AACTTAATTT  ACTAAATTA  AACTCATGAA  AAATTAATGC  GTGAGTTTCT  960
961  TTTTATAAGC  AAAAAGAGTA  TATTTTAAAA  AAAAATAAAA  GAATATAATG  GCCATAGAAG  1020
1021  GTACCAAAAA  TTGGTACAAT  GCTTTCCTAA  AAAAGAGTAT  AACTTTTTTG  GGGGCCCTAA  1080
1081  ATTTTGATAT  AATTTATTTA  AAATAAATG  AATTTTAGGA  ATATCCATCT  TAAGTGGAGT  1140
1141  TAGAAACATG  TAAAGGATAT  TAATCTAGA  AATAAATAAA  TAATAAATTT  AAGAAAAAAA  1200
1201  GAATAATATT  AAAAGCTTAC  AACAAATTTT  TCGTCTAAG  ATATATTAAT  GAACAACGTT  1260
1261  CTATAATGG  CTTCCAGCT  TAGTGGTATG  CTTTGACAAT  TGTGCCAGG  GATCA  1315

```

Figure 2. Sequence of *A. membranaceus* var. *mongholicus* fragment A1. SCAR was generated using primers HG3 and HG4 (underlined). RAPD primer OPB-2 is boxed.

```

1  TCGGTGCTTG  CCCCTCACA  AAAGTGACCA  GATACGACGA  ACGCTATCTG  ATAGAGCTGT  60
61  TCGGATTCG  GCTCCAGTC  AGCTGGAAT  TCGCGCAACA  ACTCGGCGAA  GTGGCTCCG  120
121  TTCCAATCTG  AATTGCGCTC  CAAGTCAGTT  GTTAGTGGAG  CCTAAAATCG  TGCCTTGACT  180
181  TCGGCACAAA  GCAGTGTCTG  AAGCCTATAA  AAAGGCTCTT  CCTCAGCTTG  ACGAAATCAG  240
241  ATCGAAAAAC  AGCAAACTCT  CCTCCGAAAA  TTCTCTCTC  TCTAAAATTC  GTGACTGGCC  300
301  TACGAGCCAG  ATTCTCTCTC  TTCTCTCTCT  TTCTGAGAG  TGGCCTACGA  GGCATATTC  360
361  CGAGTGGTTA  TAAACCATAT  TGAGAGGTGT  ATATCTCGAG  CGATTACTGA  CTGTCCAGTC  420
421  ATAATCGTAA  CTGGGCTGTT  TTATCCTGGG  GGCCTCGTGG  TTGATAGTCT  GCTTGCACCA  480
481  TCGAGCAGTG  CCAAGGAAAG  TCTTAAAGAG  AGCGACCTAG  TCGCGACTC  ATCCCACTAC  540
541  TACTCTCGCC  CAAGCAGGCT  CAACAATACG  AGTCCGCTA  AGCACGCA  588

```

Figure 3. Sequence of *A. membranaceus* fragment A2. SCAR was generated using primers HG7 and HG8 (underlined). RAPD primer OPC-14 is boxed.

Most of the amplified fragments were within the range of 0.1 to 2 Kb. A number of putative species-specific bands were noted; however, most of them were faint or close to other bands. Only the fragments verified by repeated tests were considered to be potential markers. Using the RAPD primers OPB-2 and OPC-14 (Table 1), stable specific bands were identified (Figure 1). A 1.3 Kb polymorphic fragment A1 amplified by OPB-2 was specific to *A. membranaceus* var. *mongholicus* (Figure 1A, lane 1).

A band amplified from *A. membranaceus* with similar size but slightly smaller than A1 was observed on lane 2. However, the band did not share any sequence similarity with A1 (data not shown). RAPD markers were not necessarily locus-specific⁽¹⁴⁾; polymorphic profiles could not be interpreted in terms of loci and alleles. In this case, fragments of similar size from lane 1 and 2 were not homologous. PCR of OPC-14 resulted in two specific bands, a 0.6 Kb fragment A2 was distinct to *A. membra-*

naceous, and a 0.8 Kb fragment H1 was to *H. polybotrys* (Figure 1B). These DNA fragments were subsequently cloned to pGEM T Easy Vector and subjected to sequence analysis.

II. Sequencing and Amplification of SCAR Markers

The sequences of RAPD fragments A1, A2 and H1, represented as specific markers of *A. membranaceus* var. *mongholicus*, *A. membranaceus* and *H. polybotrys*, were illustrated in Figures 2, 3 and 4, respectively. No

significant sequence homology was identified among these sequences and the entries in GenBank. Primers of HG3 and HG4 from A1, HG7 and HG8 from A2, as well as RC3 and RC4 from H1 (Table 1) were designed and used to amplify these DNA fragments under high stringent conditions. Single bands of 0.9 Kb, 0.5 Kb and 0.7 Kb (Figure 5A, B and C) were obtained in *A. membranaceus* var. *mongholicus*, *A. membranaceus* and *H. polybotrys*, respectively as SCAR markers which were shorter than the original RAPD fragments A1, A2 and H1. Two SCAR analyses were performed to test the fidel-

```

      RC3
1  TGCGTGGCTTG  GGGCAACATG  GCTGAAAGCT  TCCAGCACAT  ACTGCTGTCT  CAGATGTTTC  60
61  CTCGAATTGCT  TCTTGAGATT  CCGCTACGCA  CTCGCGGGCG  GGGCGAAGGC  TTCCCATCCA  120
121 TGGTGTGCGG  GCGTCTGAAA  GATCCATCTT  CCTCGTAGGC  GCTCTTTGAT  GGTGACAAAA  180
181 TGGGGAGAGG  TAGCAGTTGC  CTGATTAAAC  TTTTAGTTTA  AGTTTCTTTT  TTTATTATTT  240
241 CTTATGCTCT  AAAAATGTTT  TCCTTGTTTT  GTGTGTATGC  TTTTAGTTTC  TCCAGTATGT  300
301 ATCTAAATTT  TTAATTGTG  TTTATTTCGT  TTGGAACAAT  GTACCTGCAC  CCTTATATTA  360
361 ATGCAAATCA  GTGTGTGAA  ATAAATATCT  CTACAAATCA  TACTTTGCAT  CAACTGAGGG  420
421 GGAGTTTTTT  CCTCCACAA  AAGCATTCA  TAATAACATG  CATCAACTCA  GGGGGAGTTT  480
481 CTCTCTTCC  TTCTACTTAT  GAATATAAAA  ACTTAATATA  TCATCTTAGA  TAAGTTTATT  540
541 ATCACCAGAA  ATGGGGAGAT  TGTAAATCA  AGATCTCAAT  ACATGTTTTG  ATGATTAACT  600
601 AAGTCTCTGA  GAGATCAACC  TAAGTTTCA  TATCCCACTA  ATGGTTTCTA  TCTAGTTTAT  660
      RC4
661 AAAGACAGGA  AAAACAAGCT  CTAGATAACT  CTCCCGGAC  ATCCAGACA  AAGCTGGTCA  720
721 AGTCTATCAG  GACAATGTCA  AGACAAAAT  AAGAATATTT  ATCAGTCATT  AAAATACATA  780
781 AGTTGCATCT  CTATCCGCTT  GCTTAGAGA  GCTAAAGAGG  AGAGAAAATC  AAACCTATCC  840
841 TTCTCAGGCA  AGCAAGCA  898
  
```

Figure 4. Sequence of *H. polybotrys* fragment H1. SCAR was generated using primers RC3 and RC4 (underlined). RAPD primer OPC-14 is boxed.

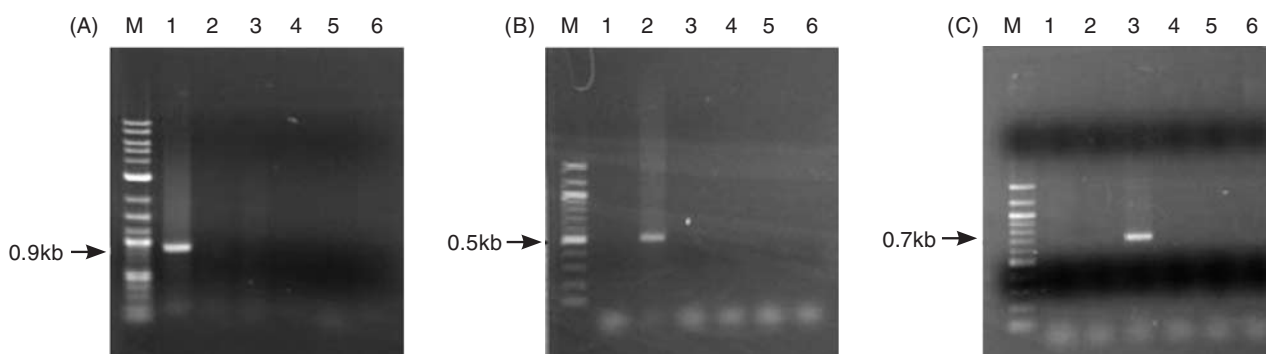


Figure 5. SCAR analysis of three other *Astragalus* plants using primers: (A) HG3 and HG4; (B) HG7 and HG8; (C) RC3 and RC4. Lane 1: *A. membranaceus* var. *mongholicus*; Lane 2: *A. membranaceus*; Lane 3: *H. polybotrys*; Lane 4: *A. spruneri*; Lane 5: *A. obseurus*; Lane 6: *A. garbancillo*; M: (A) 2-Log molecular weight marker; (B) and (C) 100-bp molecular weight marker.

ity of SCAR markers. Firstly, DNA samples of three other *Astragalus* species *A. spruneri*, *A. obscuru*, and *A. garbancillo* extracted from fresh plants were examined by PCR. No band was found in these three *Astragalus* plants (Figure 5). SCAR markers were amplified only in the corresponding species rather than in other *Astragalus* plants. Secondly, two samples of *Astragalus* radix products purchased from local market were put to test. SCAR analysis indicated that one was *A. membranaceus* var. *mongholicus* (Figure 6, Lane 4) and the other was *H. polybotrys* (Figure 6, Lane 5). Under microscopic examination, one sample with grayish-yellow surface color and a brown peripheral cambium ring, containing stone cells but no calcium oxalate crystals was identified as *A. membranaceus* var. *mongholicus*. The surface color of the other sample was reddish-brown with calcium oxalate crystals fibers but no stone cells, was authenticated as *H. polybotrys*^(1,3). The microscopic examination of these two *Astragalus* radix samples agreed with the SCAR results.

Paran and Micheltore (1993)⁽⁸⁾ indicated an advantage over SCARs by conversing a dominant RAPD marker into a codominant SCAR marker. However, in our study, the polymorphisms were retained as the presence or absence of bands when the corresponding SCAR primers were applied. Hence, these SCAR markers of

Astragalus medicines would still be considered as dominant markers.

Several approaches were employed to study the phylogenetic relationships of *A. membranaceus* var. *mongholicus*, *A. membranaceus*, and *H. polybotrys*. The DNA sequences of 5S rRNA spacer, ITS, and 18S rRNA of these plant species and other *Astragalus* taxa were examined by Ma *et al.*⁽¹⁵⁾ and Dong *et al.*⁽¹⁶⁾. Since *A. membranaceus* var. *mongholicus* was considered as a variety of *A. membranaceus*, they both share the greatest homology among those DNA sequences; rRNA sequences thus are not suitable to distinguish these two *Astragalus* medicines. It is likely that the rRNA sequences are more useful in identifying the inter-species rather than intra-species of *Astragalus* spp.

In conclusion, the identification and control of medicinal materials are closely connected to the efficacy of chinese medicine, which is the fundamental issue in the development of herbal drugs. Authentication of herbal material demands fast, reliable and reproducible protocols. In this study, we have demonstrated that two botanical origins of *Astragalus* radix and a common adulterant *H. polybotrys* could be distinguished by using sequence-specific designed SCAR markers.

ACKNOWLEDGMENTS

The authors wish to thank Ms. Shu-Jeng Kuo for assistance in identifying the specimens, the Millennium Seed Bank Project of the Kew Garden for providing seeds of *A. spruneri*, *A. obscuru*, and *A. garbancillo*. We also thank Mrs. Marilyn Ritzier Liu for critical review of the manuscript.

REFERENCES

- 1 Williamson, E., Sudberg, S. and Sudberg, E. 1999. *Astragalus* root. In "American Herbal Pharmacopoeia and Therapeutic Compendium". pp. 3-6. Herbalist, R. U. ed. American Herbal Pharmacopoeia. CA., U. S. A.
- 2 Tung, C. F., Ho, Y. L., Tsai, H. Y. and Chong, Y. S. 1999. Studies on the commonly misused and adulterated Chinese crude drug species in Taiwan. *Chin. Med. Coll. J.* 8: 35-46.
- 3 Wang, B. Q., He, Z. Q., Zhang, J., Lu, J., Rao, W. W., Wu, S. Z., Tian, J. G., Su, J. and Feng, X. E. 1997. *Astragali Radix*. In "Species Systematization and Quality Evaluation of Commonly Used Chinese Traditional Drugs". South-China Edition Volume II. pp. 147-183. Xu, G. J., Xu, L. S. eds. Fujian Science and Technology Publishing House. Fujian (in Chinese).
- 4 Shaw, P. C., Ngan, F. N., But, P. P. H. and Wang, J. 2002. Molecular markers in Chinese medicinal materials. In "Authentication of Chinese Medicinal Materials by DNA Technology". pp. 1-23. Shaw, P. C.,

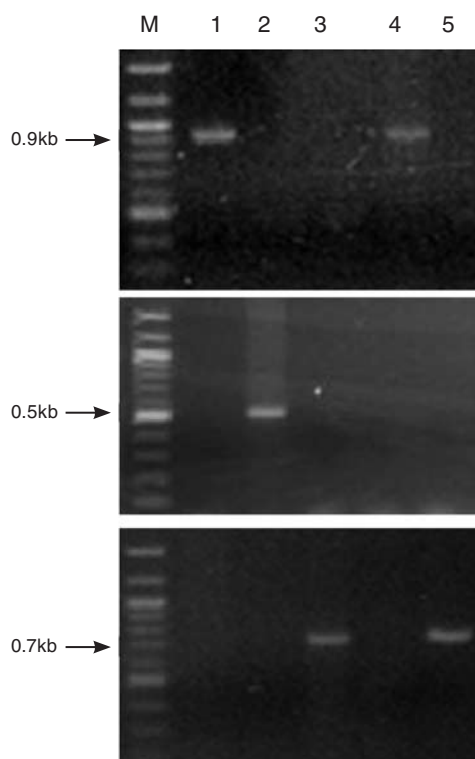


Figure 6. SCAR analysis for two Huang Qi samples using primers: (A) HG3 and HG4; (B) HG7 and HG8; (C) RC3 and RC4. Lane 1: *A. membranaceus* var. *mongholicus*; Lane 2: *A. membranaceus*; Lane 3: *H. polybotrys*; Lane 4 and 5: samples from local market. M: 100 bp molecular weight marker.

- Wang, J. and But, P. P. H. eds. World Scientific Publishing Co. Singapore.
5. Cheng, K. T., Su, B., Chen, C. T. and Lin, C. C. 2000. RAPD analysis of *Astragalus* medicines marketed in Taiwan. *Am. J. Chin. Med.* 28: 273-278.
 6. Na, H. J., Um, J. Y., Kim, S. C., Koh, K. H., Hwang, W. J., Lee, K. M., Kim, C. H. and Kim, H. M. 2004. Molecular discrimination of medicinal *Astragali radix* by RAPD analysis. *Immunopharmacol. Immunotoxicol.* 26: 265-272.
 7. Micheli, M. R., Bova, R., Pascale, E. and D'Ambrosio, E. 1994. Reproducible DNA fingerprint with the random amplified polymorphic DNA (RAPD) method. *Nucl. Acids Res.* 22: 1921-1922.
 8. Paran, I. and Michelmore, R. W. 1993. Development of reliable PCR-base markers link to downy mildew resistance genes in lettuce. *Theor. Appl. Genet.* 85: 985-993.
 9. Spooner, D., van Treuren, R. and de Vicente, M. C. 2005. Overview of molecular technologies. In "Molecular markers for genebank management. IPGRI Technical Bulletin No. 10". pp3-16. International Plant Genetic Resources Institute, Rome. Italy.
 10. Wang, J., Ha, W. Y., Ngan, F. N., But, P. P. H. and Shaw, P. C. 2001. Application of sequence characterized amplified region (SCAR) analysis to authenticate *Panax* species and their adulterants. *Planta Med.* 67: 781-783.
 11. Yau, F. C. F., Wong, K. L., Wang, J., But, P. P. H. and Shaw, P. C. 2002. Generation of a sequence characterized amplified region probe for authentication of *Crocodylian* species. *J. Exp. Zool.* 294: 382-386.
 12. Yau, F. C. F., Wong, K. L., Shaw, P. C., But, P. P. H. and Wang, J. 2002. Authentication of snakes used in Chinese medicine by sequence characterized amplified region (SCAR). *Biodivers. Conserv.* 11: 1653-1662.
 13. Murashige, T. and Skoog, F. 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. *Physiol. Plant.* 15: 473-497.
 14. Smith, R. H. 1992. Explant preparation. In "Plant Tissue Culture Techniques and Experiments". pp19-27. Smith, R. H. ed. Academic Press, Inc. CA., U. S. A.
 15. Ma, X. Q., Duan, J. A., Zhu, D. Y., Dong, T. T. X. and Tsim, K. W. K. 2000. Species identification of *Radix Astragali* (Huangqi) by DNA sequence of its 5S-rRNA spacer domain. *Phytochemistry* 54: 363-368.
 16. Dong, T. T. X., Ma, X. Q., Clarke, C., Song, Z. H., Ji, Z. N., Lo, C. K. and Tsim, K. W. K. 2003. Phylogeny of *Astragalus* in China: Molecular evidence from the DNA sequences of 5S rRNA spacer, ITS, and 18S rRNA. *J. Agric. Food Chem.* 51: 6709-6714.