INTRODUCTION

In India, *Haemonchus contortus* is one of the major parasite of sheep and goat, which causes production losses and even death in severe cases. However, the production losses are also affected by the genetic and non-genetic factors (Assan and Makuza, 2005; Mandal et al., 2005). The heavy infection of *H. contortus* decreases the packed cell volume (Howlader et al., 1996), red blood cells (Howlader et al., 1997a) and body weight gain in goats (Howlader et al., 1997b). Control of this parasite is mainly based on the use of benzimidazole (BZ) and tetramisole/levamisole. Benzimidazole is the most extensively used anthelmintics for the control of parasite since 1960s. Benzimidazole (albendazole) was found highly effective (>95%) for control of strongyle infection in sheep (Dorny et al., 1995). These drugs are preferred because of their low cost, broad-spectrum activity and high efficacy. But the widespread use of anthelmintics has led to the development of resistance (Jackson 1993; Waller 1994).

Several methods have been used for detection of BZ resistance viz. *in vivo* and *in vitro* assays. The fecal egg count reduction test (FECRT), egg hatch assay (EHA) and larval development assay (LDA) have proven to be suitable tests for detecting BZ resistance (Le Jambre, 1976; Coles et al., 1992). However, these tests are time consuming, costly, low in sensitivity and can detect resistance only when 25% of the individuals in the population are already resistant (Martin et al., 1989; Humbert et al., 2001). On the other hand, the molecular assays are highly sensitive and less expensive for diagnosis of an thelmintic resistance. These assays detect mutation at the codon 200 of the \( \beta \)-tubulin isotype 1 gene that is primarily linked with BZ resistance in nematode species. The point mutation (TTC to TAC) leads to a change in the amino acid from phenylalanine to tyrosine (Kwa et al., 1993, 1994; Ross et al., 1995; Elard et al., 1996; Elard and Humbert 1999).

Allele specific-PCR technique has been used to detect the BZ resistance in nematode species (Lehrer et al., 1995; Elard et al., 1999; Silvestre and Humbert, 2000, 2002; von Samson-Himmelstjerna et al., 2002a, 2002b; Pape et al., 2003; Winterrowd et al., 2003). AS-PCR has an advantage over the existing assays in terms of specificity, sensitivity and give quick results with less input. Recently, Álvarez-Sánchez et al. (2005) used real time PCR for the diagnosis
of BZ resistance in Trichostrongyelids of sheep, which is found to be more sensitive, rapid and inexpensive.

In India, the first occurrence of anthelmintic resistance in *H. contortus* of sheep was reported by Varshney and Singh (1976). Anthelmintic resistance in *H. contortus* has been detected through FECRT, EHA, LDA tests (Singh et al., 1992; Yadav et al., 1993; Singh et al., 1995, 1996), but information on molecular assays for BZ resistance is not available. In the present study, the aim of the study was to use an allele specific-PCR for the detection of BZ resistance in *H. contortus* of sheep.

**MATERIALS AND METHODS**

**Collection of parasite**

Adult male *H. contortus* were collected directly from the abomasum of sheep from three different locations of Rajasthan, India viz. local abattoir of Bikaner (arid region) and Jaipur (semi-arid region) as well as sheep necropsied at Central Sheep and Wool Research Institute (CSWRI) Avikanagar.

The individual abomasum was collected and put in to the polythene bag. The abomasum was opened by incising along the greater curvature and the whole contents along with mucosal surface of abomasum were washed several times with distilled water. The washings were added in to the bucket and mixed thoroughly. The contents were sieved to remove the feed particles. Remaining contents were repeatedly washed and sieved unless the remnant having parasites become clear. Individual adult male *H. contortus* was picked with the help of needle and the species was confirmed by studying their characteristic morphological features (Soulsby, 1965). A total of 162 parasites (54 from each location) were collected in PBS and incubated at 37°C for five hours. The worms were stored at 4°C till further use.

**DNA extraction**

The genomic DNA from each adult male *H. contortus* was isolated using standard protocol of Beech et al. (1994) with minor modifications. Individual worm was mixed in 224 µl of digestion mixture (comprised of 200 µl STE, 10 µl sodium dodecyl sulphate (10%), 10 µl β-mercaptoethanol and 4 µl Proteinase-K (10 mg/ml) and incubated at 37°C for 4 h. After incubation, 200 µl of Phenol: Chloroform: Isoamyl alcohol (25:24:1) was added and centrifuged at 12,000 rpm for 1 min. The aqueous phase was collected in a fresh tube and 4 µl of linear acrylamide (2.5 mg/ml), 270 µl of absolute iso-propanol and 130 µl of 7.5 M Ammonium acetate were added. DNA was recovered by centrifugation at 14,000 rpm for 20 min and pellet was dissolved in 30 µl TE buffer (pH 8.0).

Detection of BZ resistance through AS-PCR assay

BZ resistance, which is linked to the mutation at the 200 codon of β-tubulin isotype 1 gene, was detected by allele specific-PCR. Two sets of primers were used for amplifications; same reverse primer TGG 312 (5'-GGA ACC ATG TTC ACG GCT AAC-3') was used in two separate reactions with CAW 106 (5'-TAG AGA ACA CCG ATG AAA CAT T-3') as susceptible primer and TGG 331 (5'-G TAG AGA ACA CCG ATG AAA CAT A-3') as resistant primer. Primer CAW 106 annealed with complementary sequence with phenylalanine (TTC) codon, whereas primer TGG 331 annealed with complimentary sequence of tyrosine (TAC) at codon 200 of β-tubulin gene. Only the final base at the 3' end of each forward primer confers the specificity.

The PCR reaction mixture was comprised in 20 µl volume as follows; 1.5 mM MgCl₂, 200 µM dNTP's mixture, 1×Taq polymerase buffer (16 mM (NH₄)₂SO₄, 67 mM Tris-HCl (pH 8.8), 0.01% Tween-20, Bio-line), 200 nM of each primer, 2 μl of template DNA and 0.5 U Taq DNA polymerase. PCR reaction conditions were optimized using initial denaturation at 95°C for 10 minutes followed by 50 cycles of denaturation at 95°C for 30 s, annealing at 61°C for 30 s and extension at 72°C for 60 s followed by final extension at 72°C for 5 min. All reactions were carried out in Thermal Cycler (Mastercycler Gradient, Eppendorf). Amplified products were analyzed on 2% agarose gel stained with ethidium bromide. The susceptible primer (CAW 106) and resistant primer (TGG 331) amplify a product of 266 bp and 267 bp, respectively. Worms that gave amplification only with BZ-susceptible primer were designated as homozygous susceptible (SS), the individuals that amplify only with BZ-resistant primer were designated as heterozygous resistant (rS), the individuals gave amplification with both the primers were designated as homozygous resistant (rr). The genotypic and allelic frequency data were compared using χ² test (Snedecor and Cochran, 1967).

**RESULTS AND DISCUSSION**

Adult male *H. contortus* were genotyped for detection of mutation in the β-tubulin isotype 1 gene using AS-PCR technique. A total of 162 parasites consisted of 54 from each location viz. Bikaner, Avikanagar and Jaipur were used in the study. The genotypic frequencies of three genotypes (rr, rS and SS) for BZ resistance were significantly (p<0.001) different among three locations shown in Table 1.
Allele frequency was also revealed similar trends as found with genotypic frequency in all the locations. Overall, proportion of BZ resistant (r) allele was significantly (p<0.001) higher (87%) as compared to 13% prevalence of BZ susceptible (S) alleles (Table 1).

From Bikaner region 54 parasites were analyzed, of that 27 ‘rr’ type, 18 rS and 9 SS types. The AS-PCR profile of β-tubulin isotype 1 gene has shown in Figure 1. The prevalence of different genotypes varied significantly (p<0.001) with 50% ‘rr’ type, 33% rS and 17% SS types. The prevalence of BZ resistance in Bikaner was found less as compared to Avikanagar and Jaipur regions. This might be due to the harsh climate of this region, where the average annual rainfall is very less and the temperature exceeds up to 45°C. Such environmental conditions are detrimental for survival of infective stages of the parasites, causes low infection rate thereby low use of anthelmintics. The drenching of animals is practiced only once in a year in Bikaner and adjoining areas that causes the possibility of low BZ resistance in the flocks. The results indicated that high prevalence of BZ resistance found at Avikanagar, as the 98.0% individuals carry TAC allele. The high level of BZ resistance at this location is due to the frequent use of anthelmintic treatments thereby parasites have become resistant to benzimidazoles (Swarnkar et al., 1999). These results are in agreement with the study of Singh et al. (1995), who recorded 0% efficacy of benzimidazole using FECRT, and further confirmed by EHA and LDA tests (Swarnkar et al., 2001).

From Avikanagar, 54 parasites were genotyped, 50 individuals were ‘rr’ type, 3 rS and one SS type. The types of genotypes varied significantly (p<0.001) with 93% individuals ‘rr’ type, 5% rS and 2% SS type. Similar trends was also reported by Pape et al. (2003), who reported that the increasing dose of fenbendazole decreases homozygous (TTC/TTC) individuals, and increases heterozygous (TTC/TAC) and homozygous (TAC/TAC) individuals of cyathostomes parasites. In the present study, the ‘rr’ individuals were higher in the semi-arid areas (Jaipur and Avikanagar) as compared to arid area (Bikaner). This might be because of Avikanagar and Jaipur regions have almost same agro-climatic conditions, which are more favourable for development of H. contortus thereby more use of anthelmintics. Another possibility may be collection of parasites in the monsoon season when drenching practices are highest in the flocks, which may also cause the incidences of resistance in the parasites (Singh et al., 1999; Swarnkar et al., 2004).

Several in vivo and in vitro methods have been used for detection of BZ resistance in H. contortus like FECRT, EHA and LDA tests (Singh et al., 2002), however in vitro tests have low sensitivity, relatively expensive and detect the resistance only when at least 25% of the individuals within the population are already resistant (Martin et al.,

** Table 1. Genotypic and allelic frequencies of BZ resistance in H. contortus by AS-PCR technique

<table>
<thead>
<tr>
<th>Location</th>
<th>Genotypes frequency</th>
<th>Allele frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Homozygous resistant (rr)</td>
<td>Homozygous susceptible (SS)</td>
</tr>
<tr>
<td>Bikaner</td>
<td>0.50** (27)</td>
<td>0.17** (9)</td>
</tr>
<tr>
<td>Avikanagar</td>
<td>0.93** (50)</td>
<td>0.02** (1)</td>
</tr>
<tr>
<td>Jaipur</td>
<td>0.98** (53)</td>
<td>0.00** (0)</td>
</tr>
<tr>
<td>Overall</td>
<td>0.80** (130)</td>
<td>0.06** (10)</td>
</tr>
</tbody>
</table>

** Significant, p<0.001, Values in parenthesis are the numbers of individuals.

Figure 1. AS-PCR profile of β-tubulin isotype 1 gene of H. contortus. Upper lane: resistant individuals, Lower lane: susceptible individuals, M: 50 bp ladder.
1989). In contrast, AS-PCR technique is quick for detection of BZ resistance (Wheeler et al., 1995; Elard et al., 1999) and discriminates as little as 1% resistant individuals in samples of susceptible population (Pape et al., 2003). Although, AS-PCR can be influenced by many factors like annealing temperature, magnesium concentration, and concentration of Taq DNA polymerase (Silvestre and Humbert, 2000), but technique was found more sensitive, rapid and specific than in vivo and in vitro tests. AS-PCR determines the resistance status in the parasites based on their genotypes (rr, rS and SS), while in vivo and in vitro tests provide information either parasite phenotypically resistant or susceptible to benzimidazoles. In summary, AS-PCR technique is rapid and gave the reproducible results for detecting BZ resistance in *H. contortus*.

ACKNOWLEDGEMENT

The authors are highly thankful to the Director CSWRI, Avikanagar for providing the necessary facilities for carrying out the study.

REFERENCES


