Integrated parasite management with special reference to gastro-intestinal nematodes

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Abstract Domestic animals are susceptible to a large number of parasitic diseases, which lead to severe economic losses to livestock industry. So, it is necessary to control parasitic infections in these animals. Control of these helminths is undertaken mostly by anthelmintics, but because of their widespread use there is development of resistance across the globe. However, total dependence on a single method of control has proved to be non-sustainable and cost ineffective in the long term. A combination of treatment and management is necessary to control parasitism so that it will not cause further economic losses to producer as well as to livestock industry. To become practically and ecologically sustainable, parasitic control schemes need to be based on integrated parasite management.

Keywords Parasites · Livestock · Integrated parasite management

Introduction

Parasites remain a major threat to the health and welfare of animals all over the globe. Infection with Gastro-intestinal helminths have detrimental effect on animal health (Luscher et al. 2005). Economic losses associated with parasites occur in the form of morbidity, mortality, reduced FCR, inefficient production reduced weight gain, retarded

growth, decreased fertility and cost incurred on their treatment (Perry and Randolph 1999; Sahoo et al. 2002). About 250 million sheep and 300 million cattle are potentially affected by Fasciolosis worldwide (Gupta and Singh 2002). Coccidiosis is responsible for causing loss of \$400 million worldwide (Jolley and Bardsley 2006). Global production losses due to ticks and tick born diseases amounts to be 13.9–18.7US \$ billion annually. The estimated treatment cost alone for *H. contortus* per year in Kenya, South Africa and India is estimated to be US \$26, \$46 and \$103 million, respectively (McLeod 2004). Control of these helminths is undertaken mostly by anthelmintics. Because of their widespread use there is development of resistance across the globe. The strategic control of parasites is essential to minimize the production losses by reducing transmission of parasites and sustaining reproduction and optimum livestock productivity, but, total dependence on a single method of control has proved to be non-sustainable and cost ineffective in the long term (Waller 1999; FAO 2001). A combination of treatment and management is necessary to control parasitism so that it will not cause economic loss to producer (Scarfe 1993). Hence, in order to become practically and ecologically sustainable, parasitic control schemes need to be based on integrated parasite management (Waller 1993).

Integrated parasite management

The term “integrated parasite management” refers to a system where multiple approaches for control are utilized keeping into consideration economic factors, epidemiology, resistance status, the production system and management structure in place. IPM is the coordinated application of all suitable methods of parasite control in a manner that

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is cognizant of social, economic and environment aspects of production system. The outcome of IPM is the control of parasite population according to economic thresholds (Dent 2000).

IPM steps

- A. Chemical method
- B. Non chemical method

A. Chemical control method: This method relies entirely on treatment with different formulations of anthelmintics, but the use of drugs should be based on proper epidemiological studies. These epidemiological studies are carried out to prepare a bioclimatograph which helps in early prediction of the disease. Weather conditions and Geographical differences play a dominant role in determining the timing of strategic treatments (Barger 1999). The timing of peak larval availability on pasture is of crucial importance in understanding the population dynamics of the parasite. Treatments are often administered at times when the larval challenge on pasture is low and the majority of the parasite population is in the host. Chemical control is simple, cheap and can be used both therapeutically and prophylactic ally against helminths. However, their use have several drawbacks like impairing the development of natural immunity against helminths, consumer concerns regarding drug residues in food products and in environment and increasing incidence of parasitic resistance against the available anthelmintics (Thamsborg et al. 1999; Vercruysse and Dorny 1999).

I. Strategies for the use of chemical anthelmintics

- *Prophylactic treatments* Here treatments are done at regular intervals or drugs with residual effect are used. A broad spectrum anthelmintic like albendazole or a drug combination containing flukicide, anti-nematodal and anti-cestodal preparation can be used for common dosing against trematode, nematode and cestode to prevent multiple drug resistance.
- *Curative treatment* These treatments are based on clinical diagnosis. In this method, there is reduced expenses for anthelmintics, possibility of selection for resistance is significantly reduced if only some animals are treated and this will ensure the presence of a susceptible parasite population within the herd or flock, but its disadvantage is that, it requires regular monitoring which increases labour input.
- *Measures against intermediate hosts* Molluscicides like copper sulphate and *N*-tritylomorpholine are used. Molluscicides are usually applied in spring or mid-summer. The spring application is easy to

apply and highly effective, killing off wintered infected snails and parent snails which would supply the nucleus of the year's breeding population. Mid-summer applications kill off infected snails prior to emergence of summer infection of trematodes on to the pasture in late summer. Midsummer applications are not always as effective as spring applications (Soulsby 1982).

II. Proper anthelmintic use: Administration of correct dose of anthelmintic after assessing parasitic load and body weight of animals to prevent resistance is necessary. Under dosage should be avoided at all costs because it is greatly responsible for rapid development of resistance. Avoid frequent treatment of animals with anthelmintics. Continuous use of same group of anthelmintic for many years should be avoided; preferably the class of anthelmintic should be changed after 1 or 2 years of use. Monitor FECR (faecal egg count reduction) after every anthelmintic treatment to know efficacy of drug and don't use anthelmintic which have become less infective (FECR < 90 %).

III. Worm refugia: It is defined as a situation where part of the parasite population is not exposed to anthelmintic treatment, thus escaping selection for resistance (Van Wyk 2001). Refugia ensures that a level of genes remain sensitive to de-wormers. A surviving population of untreated worms dilutes the frequency of resistant genes. When fewer numbers of animals receive treatment, the refugia population remains large. Sustainable techniques such as FAMACHA fight drug resistance by increasing refugia population. Refugium has been identified as a crucial component in prolonging the use of anthelmintics.

IV. FAMACHA: FAMACHA, named after its originator Dr. Francois, stands for "FAffa" Malan CHArt was developed in South Africa due to the widespread emergence of drug resistant worms, but has been validated for sheep and goats in the United States. FAMACHA enables the selective deworming of clinically parasitized animals, while leaving healthy animals untreated. It utilizes the fact that a high proportion of *H. contortus* population is found in just a small proportion of individual sheep within a flock. On the basis of coloration of the mucous membranes of the conjunctival sac of sheep, FAMACHA classifies animals into categories (1–5) based upon level of anemia (Van Wyk and Van Schalkwyk 1990). The system treats only those animals that are anemic i.e., target selective treatment approach. This reduces the use of de-wormers, slows development of resistance and saves producers money. It also allows the producers to select those animals that are healthier, which can then be used for breeding purposes also. FAMACHA is used for diagnosis of *H. contortus* infection in small ruminants only. This method

can't differentiate anemia caused by bacterial or viral diseases and nutritional imbalances.

V. Alternative dewormers: Continuous and indiscriminate use of anthelmintics has led to development of drug resistance problems, presence of drug residues in milk and meat products as well as environmental contamination. This caused a serious concern for development of other alternative ways to combat parasitic infections. Varieties of plant products as well as other substances have been used against parasites as alternative de-wormers. For example seeds or the foliage of plants such as garlic, onion, mint, walnuts, dill, or parsley have been used to treat animals that suffer from gastrointestinal parasitism, while cucumber and pumpkinseeds have been associated with the expulsion of tapeworms from the gastrointestinal tract (Guarrera 1999). Oil of chenopodium derived from *Chenopodium am brosioides*, was used for many years in the UK to treat nematode parasite infections (*Strongylus*, *Parascaris* and *Ascaris* spp.) in monogastric animals including humans (Gibson 1965). Chenopodium is still used to treat worm infections in Latin America. In addition, male fern *Dryopteris filix-mas* and *Artemisia* spp. plants have been used against cestodes such as *Moniezia* spp. and nematodes, such as *Ascaridia* spp. in ruminants and poultry respectively (British Veterinary Codex 1965). Crude condensed tannin extracts from the leaves and stems of *Plagiochila stephensoniana* have been shown to reduce motility of third stage larva of *T. colubriformis*. The latest product to be tested on sheep for de-worming is a garlic product called Garlic Barrier. Herbs such as garlic work not by killing the worms, but by making intestinal tract healthier. Legume for the tropics and subtropics having high crude protein and condensed tannin contents are effective against worms (McNeill et al. 1998). Also diatomaceous earth has been promoted for controlling internal and external parasites. The diatom remains have microscopic cutting edges that are said to pierce the outer protective layer of parasitic worms and insects causing dehydration and death (Table 1).

Evidence of the anthelmintic properties of plants and plant extracts is derived primarily from ethno veterinary sources. The use of ethno veterinary plant preparations has been documented in different parts of the world (Anon 1994, 1996; Waller et al. 2001; Wanyama 1997a, b; Watt and Breyer-Brandwijk 1962).

B. Non chemical methods

I. Good management: Good management has direct effect on the health of animals. Good sanitation is the key aspect of good management that will keep majority of parasites away from the animals. Focus should be on

providing feeders which prevent wastage and contamination. Provide clean drinking water to animals that will also reduce parasitic burden. Increasing stocking rate will increase contamination of the pasture by enhancing the availability of the larval stages concentrated in lower part of the herbage. Also the scarcity of grass may induce animals to graze closer to faeces than otherwise. A high stocking density will also favour the spread of ecto-parasitic conditions such as pediculosis and sarcoptic mange where close contact between animals facilitates the spread of infection. Animal sheds must be well ventilated and lighted to maintain required humidity and circulation (Madke et al. 2010). Always keep the manure by making heaps so that eggs, larvae, cysts or other stages of parasites are killed due to the heat generated during composting (William and Warren 2004). Isolation and de-worming of new animals that are arriving in herd should be ensured that will also minimize parasitic burdens and spread of infection (Table 2).

II. Clean and safe pastures: Clean pasture is a pasture with a nil or very low risk infection when animals are firstly grazed on it (Younie et al. 2004). It can be prepared by rotation between a susceptible species and unsusceptible species and the use of land for forage or crops (Thamsborg et al. 2004).

Safe pastures are referred to those that are minimally contaminated. It takes approximately 3–9 months for pasture infectivity to decrease significantly for most of species depending on climate and timing of year (Barger 1999). An exception to this is *Nematodirus* spp. whose eggs are able to survive on pasture for more than a year (Younie et al. 2004). It is also important to know for which period of time animals can remain on pasture until next generation of infective larvae has developed (Table 3).

Guidelines for contamination of safe pasture in temperate climates (Thamsborg et al. 2004; Eysker et al. 2005)

	Spring	Summer/Autumn
Infected animals	Up to 6 weeks	2–3 weeks
Uninfected animals	Approx. 8–12 weeks (Mid June)	At least 6 weeks

III. Pasture resting and rotation: Pasture resting is seldom a suitable strategy. Grazing must be inhibited for 6 months during cold weather or for 3 months during hot, dry weather. Rotational grazing is based on rapid pasture movement (every 3–4 days) to provide safe pasture, followed by long spelling (30 days or more) based on duration

Table 1 Chemoprophylactic measures against important parasitic diseases of domesticated animals in Kashmir valley (Deptt. of vety. Parasitology, SKUAST-K, Shuhama)

S. no	Diseases	Dosing schedule	
1.	Dosing against Fasciolosis in sheep in endemic areas	Late winter/early spring (15th Feb. to 14th March) Early summer/Mid summer (15th June to 14th July) Mid autumn/late autumn (15th Oct. to 14th Nov.)	Very important in marshy and low lying areas where sheep are fed mainly on paddy hay during winter but can be followed in all parts of Kashmir valley, if needed
2.	Dosing against fasciolosis in cattle in endemic areas	Late spring (1st to 31st May) Late autumn (1st to 30th Nov.)	Very important in marshy and low lying areas where cattle are fed mainly on paddy hay during winter but can be followed in all parts of Kashmir valley, if needed
3.	Deworming against round worms in sheep, cattle and horses	Late spring (1st to 31st) Late autumn (1st to 30th Nov.)	In all areas of Kashmir valley
4.	Deworming against tapeworms in calves, lambs, kids and foals	Late autumn (1st to 30th Nov.)	In all areas of Kashmir valley
5.	Prophylactic measures against ectoparasites like ticks and mange	Late spring (1st to 31st May) Late autumn (1st to 30th Nov.)	In all areas of Kashmir valley
6.	Preventive medication against poultry coccidiosis	Prolonged or continuous use of coccidiostatic compounds in feed and water	All commercial poultry farms but their use should be discontinued at a suitable period before marketing of birds depending on drug used

Table 2 Status of anthelmintic resistance in organized and unorganized sectors of Kashmir valley (Deptt. of Veterinary Parasitology, SKUAST-K, Shuhama)

S. no	Anthelmintic used against nematodes	Resistance status	Organized farm (goats)	References
1.	Fenbendazole	Moderate	MRCSG, Shuhama, Srinagar	Bihaqi (2013)
2.	Ivermectin	Slight	MRCSG, Shuhama, Srinagar	
3.	Closantal	Moderate	MRCSG, Shuhama, Srinagar	
S. no	Anthelmintic used against nematodes	Resistance status	Organized farm (Sheep)	References
1.	Fenbendazole	Slight	MRCSG, Shuhama, Srinagar	
2.	Ivermectin	Slight	MRCSG, Shuhama, Srinagar	
3.	Ivermectin	Slight	Government Sheep Breeding Farm Poshnar, Handwara,	
4.	Fenbendazole	Moderate	Government Sheep Breeding Farm Poshnar, Handwara,	
5.	Fenbendazole and ivermectin	Moderate	Government Sheep Breeding Farm, Zawoora, Shopian	

However, no anthelmintic resistance has been detected in unorganised sector of Budgam district against ivermectin/fenbendazole and closantal in sheep (Shahana 2013) and North zone of Kashmir Valley against ivermectin/fenbendazole/oxyclozanide in cattle (Aiman 2014)

of parasitic life cycles (Barger et al. 1994). Rotational grazing has been proved to be effective in tropics (Chandrawathani et al. 2004) but can't be applied to temperate climates for several reasons, one of which is the longer time required for pasture to become safe again (Barger 1999).

IV. Alternate grazing: In alternate grazing, different age groups of the same species or different species graze the pastures in sequence. It is based upon the fact that many parasites show little cross-infectivity between species and/or the reduced susceptibility of different host species. Cool moist weather prolongs larval survival hence this is less

Table 3 Sheep breed comparisons for resistance to internal parasites

Resistant breed	Comparison	Parasite species	References
Targhee	Rambouillet	Osp, Nsp	Scrivner (1964)
Scottish black face	Finn dorset	Hc	Altaif and Dargie (1978)
Border Leicester × Merino	Merino	Osp	Donald et al. (1982)
Florida native	Rambouillet	Hc	Jilek and Bradley (1969)
Florida native	Dorset × Rambouillet	Hc, Tsp.	Zajac et al. (1988)
Florida native	Barbados	Hc	Courtney et al. (1985)
Florida native	Suffolk	Hc	Ruvuna and Stephens (1997)
Red Maasai	Merino, Corridale Hampshire	Hc	Preston and Allonby (1978)
Red Maasai	Dorper	Hc	Baker et al. (1994)

Hc = *Hemonchus contortus*, Osp = *Ostertagia* spp., Nsp = *Nematodirus* spp., Tsp = *Trichostrongylus* spp.

Table 4 Different fungi used for biological control of nematodes

Types of fungi	Example	Target nematode
Egg parasitic	<i>Paecilomyces lilacinus</i> , <i>Verticillium clamydosporium</i>	<i>Ascaris</i> spp., <i>Trichuris</i> spp., <i>Nematodirus</i> spp.
Predaceous	<i>Arthobotrys oligospora</i> , <i>A. robusta</i> , <i>A. superba</i> , <i>A. conoides</i> , <i>A. totor</i> <i>Duddingtonia flagrans</i> , <i>Monacrosporium</i> <i>eudernatum</i>	<i>Strongyloides papillosus</i> , <i>Oesophagostomum</i> spp. <i>Haemonchus</i> spp., <i>Cooperia</i> spp., <i>Oesophagostomum</i> spp., <i>Dictyocaulus</i> spp., <i>Nematodirus</i> spp., <i>Ostertagia</i> spp., <i>T. colubriformis</i> , <i>H. contortus</i> , <i>Teledorsagia circumcincta</i> , <i>Oesophagostomum</i> spp.
Endo-parasitic	<i>Drechmeria coniospora</i> <i>Harposporium anguillulae</i>	<i>Ostertagia ostertagi</i> , <i>O. circumcincta</i> (Santos and Charles 1995) <i>Haemonchus contortus</i> , <i>Trichostrongylus</i> (Charles et al. 1996) <i>T. Colubriformis</i>

efficient in temperate climates compared to tropical and subtropical regions. It can be followed between cattle and horse, horse and sheep, cattle and pig or young ones followed by adults etc. (Table 4).

V. Mixed species grazing: This is implemented either by concomitant or by alternate presence of two hosts on shared pastures. It has been proved effective in particular for small ruminants to limit the populations of *H. contortus* (Marley et al. 2006). Success has been obtained in case of Pigs and cattle (Thamsborg et al. 1999), horses and small ruminants. Its limitation is that nematode specificity is not exclusive as a few larvae of cattle might establish in sheep/goats and reciprocally (Armour et al. 1988).

VI. Grazing strategies: The main function of any grazing system is to provide safe/clean pastures on which animals can safely graze. Majority of larvae usually crawl only one inch from the ground onto herbage, so not allowing animals to graze below that point will cut down

lot of infestation (Wells 1999). Also larvae migrate from the manure not more than 12 inches from the manure pile. If livestock are not forced to graze close to their manure, they will eat fewer larvae. Another strategy is to wait until the dew has lifted from grass or grass has dried after a rain.

VII. Nutritional management: Well-nourished animals cope better and overcome infection with parasites quicker than mal-nourished ones (Wells 1999). Vulnerable groups are young lambs and kids and their mothers. Two factors that play key roles in protection from nematode infection are protein availability and balanced mineral supply (Sykes and Coop 2001). Improved nutrition leads to an increase in host resilience. Adequately milk fed calves are markedly less infected by *Hemonchus*, *Cooperia* and *Oesophagostomum* (Geurden et al. 2008). Increased protein intake, decreases the extent of pathophysiological consequences after a trickle infection of sheep with *Haemonchus contortus*. Fish meal supplementation results in an increase in the concentration of mast cell proteinases and elevation in

the levels of circulating eosinophils (Van Houtert et al. 1995). Administration of copper oxide wire particles to young lambs reduces the establishment of the abomasal nematodes (*H. contortus* and *O. circumcincta*). There is an extended period of release of copper from the particles, which becomes lodged in the abomasal mucosa with a resultant persistent effect against those species susceptible to copper. Limitation include that diet with additional protein does not affect initial establishment of nematode infection. Hence nutrition can be used only to reduce consequence of disease and not the disease itself.

VIII. Improvement of animal resistance through selective breeding: Genetic selection either aimed at producing more resistant or resilient animals clearly has the potential to provide a sustainable means of dealing with nematodiosis and thus reduce our dependence on chemoprophylaxis. The Idea is to use only those animals that show either an inherently occurring resistance or resilience to nematode challenge (Bishop et al. 1996). It is possible to exploit genetic variation in resistance to nematode parasites of sheep by selection (Gray 1997). The selection for resistant animals is possible within different animals as well as within different breeds of sheep and goats (SAC 2000). Worm egg count is a moderately heritable trait ($h^2 = 0.25\text{--}0.30$) (Woolaston and Eady 1995). Grazing of resistant animals leads to a reduction in the number of infective larvae on pasture. Advantages include reduced use of anthelmintics, reduced risk of residues in animal products, but it requires increased monitoring and record keeping.

IX. Biological control: Biological control is operationally defined as the action of natural enemies which maintain a host population at levels lower than would occur in the absence of the enemies (Waller and Faedo 1996). Biological control of nematode parasites is targeted at the free living stages on pasture, unlike virtually all other methods of control which focus on the parasitic stages within the animal (Waller 1999). Agents of biological control include indirect and direct. Indirect agents work by breaking parasitic life cycles e.g. birds/dung beetles and earthworms. Earthworms destroy nematode eggs and larvae by digesting them or transferring them to deeper layers of soil. Dung beetles act by breaking up pats and partially burying the manure (Gronvold et al. 1996). Adult beetles use the liquid contents of manure for their nourishment and some species form dung balls which they bury and lay their eggs within it. Direct agents like (protozoa e.g. *Theratomyxa weberi*; bacteria e.g. *Myxobacteria* spp. and *Pasteuria* (*Bacillus*) *penetrans*; viruses e.g. baculovirus and fungi) work by acting directly on the parasites causing their destruction. Fungus is currently deemed to be most important agent of biological control. Control by fungus is

made by capturing the free living larval stages before they migrate from dung to pasture to complete their life cycle following ingestion by grazing animals. These fungi used are egg parasitic/predaceous/endoparasitic.

Advantages of biological control include economically sustainable and cost effective method with very little or no side effects. Its agents are self perpetuating, the effects are permanent i.e., once established leave no residual effect and does not interfere with the concept of organic farming. Disadvantages are that it requires subsequent use of parasiticides as it is not efficient enough to remove the severe infections, takes time to get established thus acting very slowly. It is very unpredictable and can be erratic, being highly effective at one place and not as effective at another similar place.

X. Immunoprophylaxis: Parasitic vaccines

Lung worm vaccine: The first and most successful anti nematode vaccine to date is irradiated attenuated live vaccine against the bovine lung worm *Dictyocaulus viviparus*. This vaccine consists of two doses of 1000 irradiated larvae given at an interval of 1 month. The first dose should be given when calves are of 8 weeks of age because vaccination at an age earlier to this has not remained successful. The vaccination proved to be 89 % effective in preventing clinical lung worm diseases.

Hookworm vaccine: This commercial vaccine developed against canine hook worm and was released in 1973 by Miller. The double vaccination by 1000 larvae given s/c, irradiated at 40 Kr protected pups against the severe challenge and prevented completely the expected morbidity and mortality associated with heavy challenge by normal larvae. It does not induce sterile immunity allowing the single worm to become mature and produce eggs, together with high cost of production that led to withdrawal of vaccine in 1975.

Barbervax: This is first commercially available subunit vaccine against *Haemonchus contortus*. The vaccinated animals showed 80 % overall reduction in faecal egg count. This is a hidden antigen vaccine. Usually 5 doses for lambs during the summer *Haemonchus* risk period are given. (Smith 2014).

Although vaccines have been developed against some parasitic diseases but for most of the important parasitic diseases no vaccine is available due to following difficulties:

Lack of knowledge about antigens that induce protective immunity, inability to obtain parasitic antigen in bulk (cannot be cultured in lab), evasion of host's immune response, extreme antigenic complexity and antigenic variation of parasites (Smith 1997).

Conclusion

Although there are different ways of combating parasitism, but each control method in use at present has various limitations. The general opinion is that strategic use of anthelmintics combined with better management practices will help in reducing parasitic burdens to considerable levels which in turn will reduce mortality and production losses to a greater extent.

Techniques such as increased pasture management, smart drenching, FAMACHA and selective parasite resistant animals can help to manage internal parasites. These techniques reduce dependence on dewormers and lead to a more sustainable parasite management program. New techniques such as copper wire particles and nematode trapping fungus are being researched and developed. These developments may increase the tools available to battle internal parasites of animals. For strategic anti parasitic treatment use of proper drugs at proper dose level and at proper time of year based on epidemiological studies should be practiced. However selective deworming of heavily infected animals in a herd after assessing parasitic load may also be employed as and when needed. Suppressive treatments as well as more frequent treatments lead to a rapid development of resistance to anti parasitic drugs, hence should be avoided at every step.

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