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Influence of advancement of age on intensity of strongyle infection and performance in sheep selected for resistance/resilience to infection

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ABSTRACT

An analysis was made to observe the influence of advancement of age on intensity of strongyle infection (predominantly *Haemonchus contortus*) and performance in sheep (Malpura and Avikalin breed) selected for improving the genetic resistance / resilience to infection. All the data pertaining to faecal egg counts, body weights, greasy fleece yield and disposal rate were classified according to age as up to 1 yr, 1–2 yr, 2–3 yr, 3–4 yr, 4–5 yr and > 5 yr. The monthly intensity of strongyle infection showed similar influence of advancement in age of animal in both the resistant and susceptible lines of both the breeds. Intensity of strongyle infection was significantly higher in animals of S-line across all the age groups. Within line, animals up to 1 yr of age had significantly higher faecal egg counts, particularly during wormy season. Monthly intensity of infection showed marginal rise in R-line animals in older animals (>1 yr of age), and in animals >5 yr of age compared to those between 1–5 yr during wormy season. Within line, younger animals (up to 1 yr of age) had significantly higher average daily gain in body weight (21.45 g in S-line to 25.82 g in R-line of Malpura; 29.09 g in R-line to 29.45 g in S-line of Avikalin) compared to other age groups. In adult animals (> 1 yr of age) during summer (April to June), body weights were usually either maintained (in S-line) or reduced marginally (in R-line) without much appreciable difference. In monsoon season there was evident rise in magnitude of daily weight gain up to 2–3 yr of age in both the lines. There was nonsignificant variation in annual greasy fleece yield among both the divergent lines across all the age groups. The disposal profile revealed that maintenance of animals in resistant line without anthelmintic intervention had similar pattern of disposal as in animals of susceptible line maintained with anthelmintic intervention. The present study demonstrated that the animals selected for resistant line not only restricted the use of anthelmintics but also led to low contamination of pasture due to low mean FECs compared to their counterparts in susceptible line, which required one strategic drench every year and contributed more eggs on pasture in grazing area. Animals of resistant line served as valuable resource for *refugia* and maintenance of anthelmintic efficacy. The acquired resistance to strongyle infection in sheep was unaffected by advancement of age of animal.

Key words: Age, Gastrointestinal nematodes, Growth, *Haemonchus contortus*, Performance, Sheep

Gastrointestinal nematodosis is associated with huge economic losses (Singh *et al*. 2011) particularly in resource poor regions of the world (Cernanska *et al*. 2005). Infection with *Haemonchus contortus*, which inhabits the abomasum in sheep and goat, predominates in both semi-arid and arid agroclimatic conditions (Swarnkar and Singh 2012). There are many associated risk factors influencing the incidence and intensity of gastrointestinal nematodes including age, sex, breed, husbandry or management practices, grazing resources and climatic condition. Vlassoff *et al*. (2001) demonstrated that the effect of helminthic infection on production of particular livestock species depend mostly on the age of animals, breed, parasite species involved and intensity of worm populations within a host. The sole dependence on chemotherapeutic measures and resultant rapid emergence of anthelmintic resistant strains in parasite population exerted an increasing pressure for use of alternative worm management strategies such as breeding parasite-resistant animals. This means that to ensure their own survival, sheep farmers should modify selection for production traits to also increase the ability of their sheep to withstand worm challenge, in addition to using other methods aimed at reduced selection for drug resistant worms. To improve the resistance / resilience to GINs in sheep, a study through selective breeding is being carried out since July 2004 at the institute. With the hypothesis that younger animals not capable of exerting a strong acquired immune response against the parasites are less resistant and acquired resistance improves with age, an analysis was made to observe the influence of advancement of age on intensity of strongyle infection and performance

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in sheep selected for improving the genetic resistance / resilience to infection.

MATERIALS AND METHODS

The work on creation of divergent lines resistant to strongyle infection (particularly *Haemonchus contortus*) was initiated in July 2004 through sire-wise evaluation and selection of newly born lambs every year in both native Malpura and crossbred Avikalin (50% Rambouillet × 50% Malpura) sheep at CSWRI, Avikanagar located in the hot semi-arid region of India. Temperature varies over the year from 4°C to 46°C with average annual rainfall around 500 mm.

All the sheep were raised under semi-intensive management system and provided similar grazing/feeding conditions. Regarding supplementary feeding, concentrate mixture was offered *ad lib.*to suckling lambs from 15 days age until weaning (90 days). During post-weaning period in addition to 8–10 h grazing, dry fodder supplementation and 300 g concentrate mixture was provided. Animals were housed separately according to their ages, sex, physiological and health status in night. Prophylactic health measures against enterotoxaemia, *peste des petits ruminants* and sheep pox were practiced in the flock. For management of GINs, all the young animals (< 1 yr of age) were drenched with either closantel or tetramisole (on annual rotation) in September. Among adult animals (> 1 yr of age), only animals of susceptible line (S-line) were drenched in August or September (Swarnkar *et al*. 2008) while animals of resistant line (R-line) were not given any anthelmintic treatment after 1 year of age as their mean faecal egg counts never touched the threshold limit set for deworming at farm.

The observations on intensity of strongyle infection (MAFF 1984) and body weight were recorded at monthly interval from July 2004 to March 2012. The number of animals evaluated under each category was variable and irrespective of breed, the base population (up to 1 year of age) was 217 and 191 in R- and S-line, respectively. The younger animals evaluated in first year were subsequently grouped in next age groups for rest of its life. To evaluate the flock performance, reproduction and disposal (mortality, culling/sale, transfer, predation) profiles were determined on annual basis while greasy fleece yield was recorded for September and March clip. All the data were classified according to age as up to 1 yr, 1–2 yr, 2–3 yr, 3–4 yr, 4–5 yr and > 5 yr. The monthly data were tested for significance by analysis of variance, and means were compared by Duncan's Multiple Range Test using SPSS ver 16.

RESULTS AND DISCUSSION

Intensity of strongyle infection: The monthly intensity of strongyle infection showed similar influence of advancement in age of animals in both the R and S lines of both the breeds. In general, intensity of strongyle infection was significantly ($P<0.001$) higher in animals of S-line across all the age groups. Within line, it was observed that younger animals (up to 1 yr of age) had significantly ($P<0.001$) higher faecal egg counts (FEC), particularly during wormy season. Relatively higher intensity of strongyle infection was noticed on majority of occasions in crossbred Avikalin sheep compared to native Malpura sheep. Animals of R-line posses significantly lower FECs compared to their counterpart in S-line. In younger animals (up to 1 yr of age), the mean monthly FEC ranged from 4.1±2.5 (July) to 1,682.6±175.3 epg (September) in R-line and from 5.2±2.3 (July) to 4609.8±413.3 epg (September) in S-line of Malpura sheep (Fig. 1). Similarly in Avikalin sheep, it ranged from 11.9±4.9 (July) to 2,965.6±412.6 epg (September) in R-line and from 20.8±8.9 (July) to 4,595.2±330.9 epg (September) in S-line (Fig. 2). It was obvious that in farm condition spring-born lambs exposed to naturally contaminated pasture and got opportunity to pick up infection during late June – July depending on onset of monsoon. The decline in FEC after September was attributed to anthelmintic intervention in both the line as well as to non-availability of infection on pasture due to extreme climatic conditions during winter leading to failure of translation of exogenous stages on pasture along with possible occurrence of hypobiosis phenomenon (Swarnkar *et al*. 2008).

The pattern in mean monthly intensity of strongyle infection among older animals (>1 yr of age) of R-line exhibited that it remained almost similar during climatic extremes (both during summer and winter) across all the age groups. However, from June to September (favourable season for translation of exogenous stages of predominant *H. contortus*), there was slight rise in the magnitude of mean monthly FECs in animals of >5 yr of age compared to animals aged between 1–5 yr. A declining pattern of similar magnitude was noticed in all age groups from October to March, even these animals did not receive any anthelmintic treatment.

In S-line the mean FECs remained almost similar from 1 to 4 yr of age and showed significant rise in 5 yr old animals. In crossbred Avikalin sheep the low infectivity persisted across all the age groups in R-line while in S-line the level of FECs maintained up to 5 yr of age and showed an increase in animals aged >5 yr. The results suggested that selection of animals for resistance to infection using FEC as phenotypic marker is effective and the trait character (low FEC) is being maintained up to 5 yr of age of sheep. The animals selected for R-line not only restricted the use of anthelmintics but also led to low contamination of pasture due to low mean FECs compared to their counterparts in S-line, which required one strategic drench every year and contributed more eggs on pasture in grazing area. Further, animals of R-line served as valuable resource for *refugia* and maintenance of anthelmintic efficacy.

Body weight gain: The magnitude of monthly body weights exhibited almost similar influence of age of animal in both the R and S lines of both the breeds. Within line, younger animals (up to 1 yr of age) had significantly ($P<0.05$) higher average daily gain in body weight (21.45 g in S-line to 25.82 g in R-line of Malpura; 29.09 g in R-

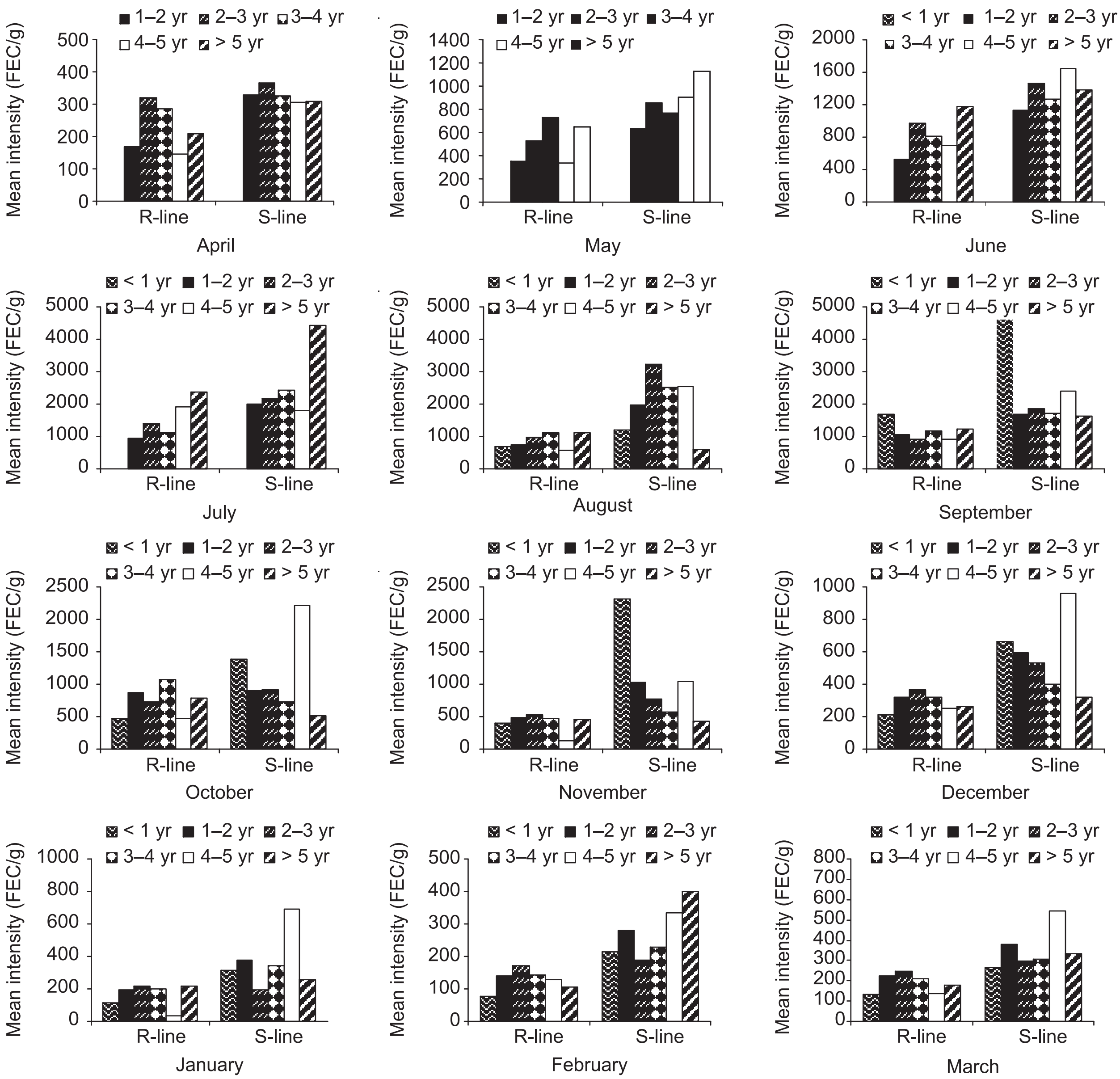

Fig. 1. Age-wise monthly mean faecal egg counts (egg per g of faeces) in Malpura sheep selected for divergent lines.

line to 29.45 g in S-line of Avikalin) compared to other age groups (Table 1).

On annual basis, in R-line of Malpura breed, rate of daily weight gain reduced linearly and remained > 10.0 g in animals of 2–3 yr of age and around 5.0 g in 4–5 yr of age while in S-line it remained around 10.0 g up to 4 yr of age with daily loss of body weight (@ 5.75 g) in fifth year of age. Like-wise in Avikalin breed, the rate of daily weight gain remained around 10.0 g in animals of 2–3 yr of age and around 5.0 g in 4–5 yr of age in both the lines. The analysis of body weight changes on seasonal basis showed that in adult animals (< 1 yr of age) during summer (April to June), body weights were usually either maintained (in S-line) or reduced marginally (in R-line) without much appreciable difference. In monsoon season there was evident rise in magnitude of daily weight gain up to 2–3 yr of age in both the lines. The results revealed that in spite of peak parasitism the animals were able to gain body weight during monsoon. A marginaly higher but nonsignificant (P>0.05) weight gain in S-line compared to R-line reflected the effect of anthelmintic intervention in S-line. The maximum daily weight gain was noticed during post monsoon season across all age groups and this could be attributed either to the availability of mature fodder in grazing area or to the growth of foetus with advancement of pregnancy. The loss in daily weight gain during spring season (January to March) in both the line could be attributed to effect of lambing.

Wool yield: In both the breeds, there was nonsignificant (P>0.05) variation in annual greasy fleece yield (GFY) among both the divergent lines across all the age groups (Fig. 3). Like-wise, the magnitude of GFY at 6- monthly clips remained almost similar in both the divergent lines.

The comparative trends in monthly body weights and GFYs between 2 divergent lines suggested resilience to GIN

Table 1. Age-wise monthly mean (±SE) body weights (kg) in sheep selected for divergent lines

Month	Line	Age (Yr)					
		Up to1	2-Jan	3-Feb	4-Mar	5-Apr	>5
Malpura							
April	R		28.8±0.8 (94)	32.0±0.9 (67)	34.3±1.3 (33)	32.4±1.0 (17)	32.2±1.2 (19)
	S		28.4±0.8 (100)	32.2±1.0 (53)	34.7±1.2 (34)	37.3±1.7 (17)	33.6±1.7 (13)
May	R		29.6±0.8 (92)	31.8±0.9 (67)	35.5±1.4 (33)	37.5±1.7 (17)	34.2±1.4 (18)
	S		28.8±0.8 (98)	32.4±0.9 (54)	34.2±1.3 (19)	34.8±1.1 (34)	33.1±0.9 (13)
June	R		30.2±0.8 (91)	31.8±1.0 (62)	33.5±1.3 (31)	31.3±1.3 (18)	33.3±1.4 (19)
	S		28.8±0.8 (94)	32.3±1.1 (47)	34.7±1.1 (32)	37.3±1.6 (17)	33.4±1.2 (14)
July	R	21.0±0.7 (17)	29.6±0.8 (87)	30.1±0.9 (59)	32.9±1.4 (29)	31.2±1.3 (17)	32.5±1.8 (16)
	S	23.1±1.1 (9)	28.5±0.7 (92)	30.4±0.9 (48)	34.4±1.2 (30)	35.9±1.8 (17)	30.7±1.6 (13)
Aug	R	24.5±0.8 (31)	30.4±0.6 (86)	31.2±0.9 (60)	33.3±1.2 (30)	31.3±1.3 (16)	30.5±1.6 (17)
	S	27.5±0.8 (24)	29.7±0.6 (92)	32.0±1.0 (49)	34.2±1.0 (30)	36.0±1.7 (17)	30.8±1.1 (13)
Sep	R	23.1±0.5 (87)	30.6±0.6 (83)	31.4±0.9 (59)	32.9±1.2 (29)	31.3±1.2 (17)	29.8±1.4 (16)
	S	24.3±0.5 (85)	30.3±0.6 (86)	32.4±0.9 (47)	34.9±1.0 (30)	36.0±1.8 (17)	31.6±1.1 (13)
Oct	R	22.9±0.5 (96)	30.9±0.7 (84)	32.3±0.8 (57)	34.0±1.3 (28)	33.2±1.4 (17)	31.3±1.6 (16)
	S	23.8±0.6 (93)	31.0±0.7 (84)	33.7±1.0 (47)	35.9±1.0 (29)	36.2±1.8 (17)	31.5±1.3 (12)
Nov	R	24.6±0.5 (98)	32.2±0.7 (82)	33.9±0.8 (58)	36.0±1.3 (29)	34.8±1.5 (16)	33.2±1.7 (16)
	S	25.1±0.7 (95)	33.1±0.7 (81)	35.8±0.9 (48)	38.1±1.0 (29)	38.0±1.8 (17)	33.3±1.2 (13)
Dec	R	25.7±0.5 (96)	32.9±0.7 (84)	34.9±0.9 (57)	36.4±1.4 (28)	35.9±1.5 (15)	33.4±1.8 (14)
	S	26.0±0.7 (91)	33.6±0.7 (79)	36.7±1.0 (48)	39.1±1.1 (27)	36.7±1.7 (15)	33.8±1.2(12)
Jan	R	26.9±0.6 (97)	33.3±0.7 (84)	36.0±0.9 (58)	38.8±1.2 (29)	36.7±1.8 (15)	33.1±1.6 (14)
	S	26.9±0.8 (87)	34.3±0.7 (87)	38.3±1.0 (48)	40.1±1.4 (26)	36.1±2.0 (15)	35.2±1.7 (12)
Feb	R	28.0±0.6 (104)	33.2±0.7 (83)	36.7±1.1 (55)	38.3±1.4 (29)	35.8±1.8 (15)	33.1±1.7 (13)
	S	27.9±0.7 (93)	34.3±0.8 (83)	37.2±1.1 (47)	38.8±1.5 (26)	34.7±1.8 (15)	35.3±1.4 (11)
Mar	R	28.3±0.7 (101)	33.0±0.9 (83)	35.9±1.3 (54)	36.3±1.2 (26)	32.8±1.7 (14)	31.9±1.4 (14)
	S	29.0±0.9 (88)	33.4±0.9 (83)	35.5±1.3 (46)	38.7±1.6 (25)	35.2±1.8 (14)	34.3±1.4 (12)
Avikalin							
April	R		28.1±0.7 (96)	29.2±0.9 (62)	32.6±1.1 (42)	32.4±1.2 (24)	32.1±1.2 (16)
	S		28.7±0.9 (84)	32.1±1.2 (47)	35.6±1.4 (26)	34.8±1.9 (13)	31.8±1.5 (17)
May	R		28.7±0.7 (98)	30.4±0.9 (62)	33.2±1.1 (42)	32.1±1.0 (22)	32.5±1.3 (16)
	S		29.8±0.9 (79)	33.4±1.2 (45)	35.9±1.5 (26)	36.5±2.2 (14)	31.8±1.7 (17)
June	R		29.1±0.7 (97)	29.8±0.9 (59)	32.6±1.2 (42)	31.9±1.3 (23)	32.3±1.3 (16)
	S		30.2±0.9 (79)	33.2±1.2 (44)	35.0±1.6 (26)	35.4±2.2 (14)	31.2±1.8 (17)
July	R	22.7±0.6 (28)	28.2±0.7 (94)	28.7±0.9 (60)	30.8±1.1 (40)	31.1±1.2 (22)	30.7±1.4 (16)
	S	22.9±0.8 (20)	29.2±0.9 (76)	31.5±1.2 (39)	31.8±1.3 (25)	34.3±2.3 (14)	31.9±2.1 (13)
Aug	R	25.4±0.6 (47)	29.2±0.7 (92)	29.3±0.8 (60)	32.0±1.0 (39)	31.8±1.3 (21)	31.0±1.2 (16)
	S	26.6±0.6 (37)	30.0±0.8 (71)	32.0±1.0 (41)	33.5±1.4 (24)	34.0±2.0 (14)	31.4±2.1 (14)
Sep	R	23.6±0.4 (111)	29.7±0.6 (94)	30.6±0.8 (54)	33.0±0.9 (39)	31.7±1.3 (21)	31.7±1.2 (16)
	S	24.1±0.5 (96)	30.7±0.8 (67)	32.7±0.9 (38)	34.1±1.4 (24)	34.0±1.8 (14)	31.1±2.3 (14)
Oct	R	23.4±0.5 (113)	29.1±0.6 (88)	31.0±0.8 (55)	33.0±0.8 (39)	32.9±1.3 (20)	31.2±1.3 (16)
	S	23.9±0.5 (98)	30.4±0.8 (63)	33.2±0.9 (36)	34.4±1.5 (23)	34.1±1.8 (14)	31.5±2.2 (14)
Nov	R	25.3±0.5 (114)	29.9±0.6 (90)	32.4±0.8 (53)	34.1±0.8 (36)	33.7±1.2 (19)	33.1±1.3 (15)
	S	25.3±0.6 (99)	32.0±0.9 (64)	34.8±0.9 (36)	35.5±1.7 (21)	35.8±1.9 (14)	33.8±2.4 (14)
Dec	R	26.1±0.5 (113)	31.0±0.6 (88)	33.7±0.8 (51)	34.7±0.8 (36)	34.6±1.2 (19)	33.1±1.1 (15)
	S	26.1±0.6 (98)	32.4±0.9 (61)	36.3±0.9 (36)	36.7±1.7 (21)	36.7±2.2 (14)	34.4±2.5 (13)
Jan	R	28.1±0.6 (108)	31.2±0.6 (88)	35.1±0.8 (50)	34.5±0.9 (34)	35.0±1.5 (19)	32.2±1.7 (11)
	S	27.9±0.7 (93)	32.0±0.8 (63)	37.6±1.1 (34)	38.1±2.0 (19)	39.5±1.6 (14)	34.2±2.8 (12)
Feb	R	29.2±0.7 (110)	31.0±0.7 (88)	34.4±1.0 (51)	33.8±0.9 (34)	34.2±1.3 (19)	31.2±1.3 (13)
	S	29.3±0.7 (95)	32.5±0.9 (65)	37.2±1.3 (33)	37.2±1.9 (20)	37.9±2.2 (14)	32.2±2.5 (11)
Mar	R	30.7±0.8 (99)	30.6±0.8 (88)	33.7±1.1 (51)	32.9±1.1 (33)	34.1±1.2 (19)	31.9±1.2 (10)
	S	31.0±0.9 (83)	32.5±1.1 (65)	36.4±1.5 (33)	38.0±1.8 (20)	35.3±2.5 (14)	32.8±2.7 (10)

Figure in parentheses indicates number of animals.

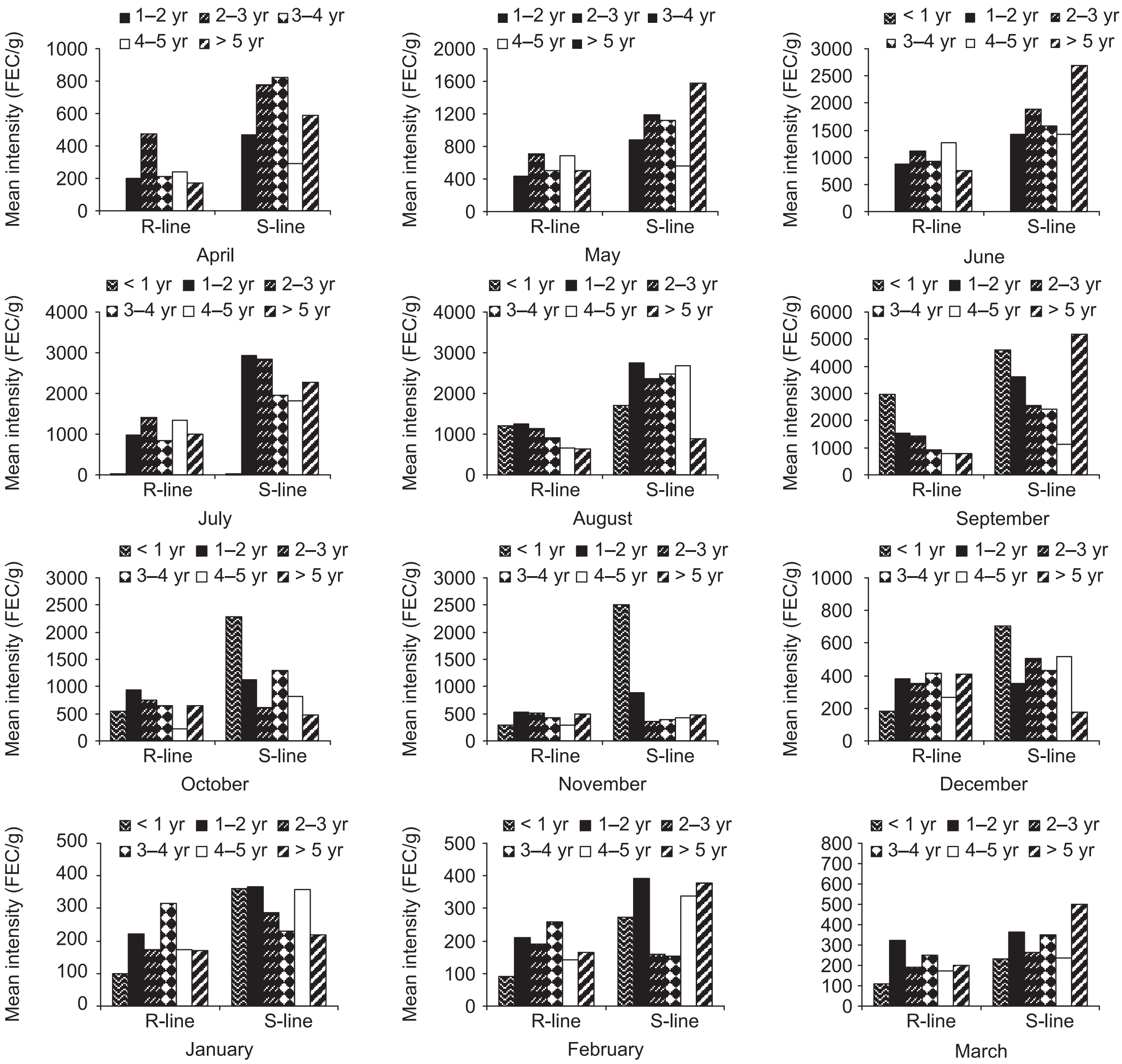

Fig. 2. Age-wise monthly mean faecal egg counts (egg per g of faeces) in Avikalin sheep selected for divergent lines.

infection in both the breeds. The animals selected for resistance to infection based on FECs could be able to maintain growth performance and produce similar quantity of wool without anthelmintic intervention at par with those selected for susceptible line and given one anthelmintic intervention at strategic point.

Disposal profile: Animals of different ages were regularly disposed off from flock through death, culling,

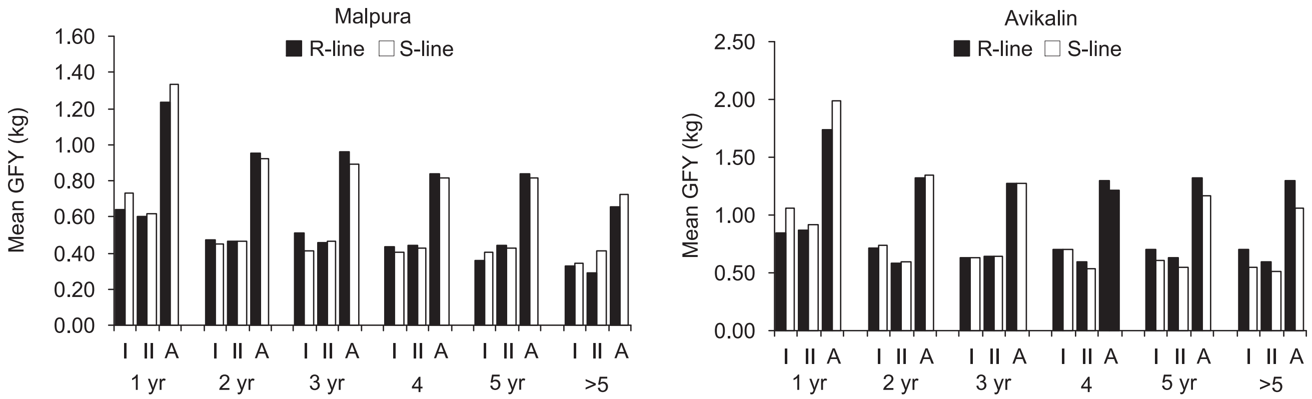

Fig. 3. Age-wise mean greasy fleece yield (kg) in sheep selected for 2 divergent lines.

predation, sale or transfer to other projects. Based on total animals available at risk, the overall disposal rate in flock from July 2004 to March 2012 ranged from 17.21% in R-line of Avikalin to 22.19% in S-line of Avikalin breed. There were nonsignificant (P>0.05) variations (Table 2) in disposal rate through any means among both the lines. In general, age-wise analysis exhibited a continuous rise in disposal rate with the advancement of age of animals. The data suggested that maintenance of animals in R-line without anthelmintic intervention had similar pattern of disposal as in animals of S-line maintained with anthelmintic intervention.

Phenotypic expression of resistance could be influenced by host–parasite interactions, such as the effects of host age and immune response to nematodes. Sheep respond to infection by trichostrongylid parasites by mounting an immune response that affects the parasite in several ways. This immune response is reported to be acquired rather than innate (Bishop *et al*. 1996, Stear *et al*. 1999). Age is an important factor in the onset of infection in host body (Magona and Musisi 2002) and several studies demonstrated significant difference among different age groups of small ruminants in relation to the prevalence and intensity of *H. contortus* infection (Colditz *et al.* 1996, Waruiru *et al*. 2000, Good *et al*. 2006, Nuruzzaman *et al*. 2012, Tesfaheywet 2012). The higher intensity of infection in younger animals is because of their low resistance or greater susceptibility due to the fact that these animals have not been exposed earlier to the infection. These appear to not to be capable of mounting a strong acquired immune response against the parasite and thus are less resistant.

The low level of parasitism in the adult animals is due to the development of significant immunity with the course of time (Tariq *et al*. 2010) as age has an effect on responsiveness or to the development of immunity causing lower worm fecundity in adult animals. Adult animals may acquire immunity to the parasites through frequent challenge and expel the ingested parasite before they establish infection (Fishes and Say 1989). The primary infection will lead to higher FEC and greater pathogenesis compared to secondary infections. Lambs appear to achieve resistance by controlling worm growth and fecundity rather than worm numbers, whereas older sheep can control both, and therefore have much lower FEC than lambs (Stear *et al*. 1999). Sargison *et al*. (2011) suggested that the effect of host age or immunity on the number of *H. contortus* surviving in the abomasum might be minimal, but host age might have an effect on the average number of eggs shed by adult female nematodes. Earlier, Silverman and Patterson (1960) stated that with the advancement of age, vigour of the animal becomes better and they develop resistance against the parasitic diseases. Gregory *et al*. (1940) compared adult ewes of different ages and found that younger ewes were more susceptible than older ewes, but that after 2 yr of age, resistance to parasitic infections was not affected by age. Adult sheep may be able to control both worm burdens and worm fecundity as a result of a better acquired immune response, whereas lambs appear to be able to regulate only worm fecundity (Stear *et al*. 1999). Based on histopathological examination it was concluded that older sheep are no more able to resist short-term primary nematode challenge than lambs, but more rapidly express a mucosal globule leukocytes/mucosal mast cells response and suppress nematode egg counts in their faeces (Douch and Morum 1993).

Baker *et al.* (1991) and Nieuwoudt *et al*. (2002) showed that the genetic correlations between log FEC and live-mass gain in sheep did not differ significantly from zero. McEwan *et al.* (1992) found strong positive correlations between reduced FEC and live mass gain (0.95) and wool growth

Table 2. Age-wise annual disposal rate (%) in sheep selected for two divergent lines

Age (yr)	No. at risk	Death	Culling	Predation/ transfer/sale	Total	No. at risk	Death	Culling	Predation/ transfer/sale	Total
	Malpura – Resistant line					Malpura – Susceptible line				
Up to 1	116	5.17	1.72	0.00	6.89	113	2.65	4.42	1.77	8.84
1-2	100	8.00	7.00	3.00	18.00	98	9.18	7.14	5.10	21.42
2-3	70	7.14	8.57	2.86	18.57	62	8.06	11.29	1.61	20.96
3-4	34	0.00	14.71	17.65	32.36	35	0.00	20.00	11.43	31.43
4-5	20	5.00	5.00	25.00	35.00	18	0.00	5.56	33.33	38.89
>5	23	8.70	21.74	4.35	34.78	14	7.14	7.14	0.00	14.28
Overall	363	6.06	7.16	4.68	17.90	340	5.29	8.23	5.29	18.81
	Avikalin – Resistant line					Avikalin – Susceptible line				
Up to 1	115	5.21	0.00	0.00	5.21	99	4.04	2.02	0.00	6.06
1-2	100	3.00	8.00	2.00	13.00	88	12.50	6.82	5.68	25.00
2-3	69	11.59	11.59	4.35	27.53	54	11.11	20.37	7.41	38.89
3-4	42	4.76	14.29	7.14	26.19	29	13.79	6.90	10.34	31.03
4-5	25	12.00	12.00	8.00	32.00	14	0.00	0.00	14.29	14.29
>5	17	5.88	23.53	5.88	35.29	18	11.11	22.22	5.56	38.89
Overall	368	6.25	7.88	2.99	17.12	302	8.94	8.28	4.97	22.19

(0.41) in New Zealand Romney sheep. Greeff *et* al. (1999) found that selection for low FEC did not result in any unfavourable changes in hogget body mass, clean fleece mass, or fibre diameter in the Rylington Merino selection line in Australia. The depression in weight gain of the infected animals may be attributed to loss of appetite (Bisset *et al*. 2001) because of the inflammatory changes in the abomasum wall cells during the larval and adult stages (Beriajaya and Copeman 1996). Further, effect of infection on body weight gain was also influenced by nutritional level as Al-Zuhairy *et al*. (1997) showed that the depression in weight gain of infected animals was very clear especially when they fed on low quality diet. Also Beriajaya and Copeman (2006) explained the effect of infection with *H. contortus* on lambs weight gain due to severe damages in the abomasal mucosa which may affect nitrogen digestion. *H. contortus* infection could also affect lamb's wool growth which may be related to anaemia and to the depression in blood serum protein (Ali *et al.* 1996).

The present study demonstrated that the animals selected for R-line not only restricted the use of anthelmintics but also led to low contamination of pasture due to low mean FECs compared to their counterparts in S-line which required one strategic drench every year and contributed more eggs on pasture in grazing area. Further, animals of R-line served as valuable resource for *refugia* and maintenance of anthelmintic efficacy. The animals selected for resistance to infection based on FECs could maintain growth and produce similar quantity of wool without anthelmintic intervention at par with those selected for susceptible line and given one anthelmintic intervention at strategic point. The acquired resistance to strongyle infection in sheep was unaffected by advancement of age of animal.

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