A Case Study of Annual Legume Seedling and Seed Populations in Commercial Crop-Pasture Systems in the Agro-Pastoral region of the Western Cape

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This study was conducted to try and quantify the condition of annual legume pastures on commercial farms in the agro-pastoral region of the Western Cape Province of South Africa. Pastures were surveyed on 114 paddocks on 30 commercial farms. The potential of these pasture paddocks to generate legume pasture, grass weed and broadleaf weed seedlings was determined by collecting soil samples during late summer to mid-autumn, wetting the samples in a glasshouse and counting the seedlings which had germinated.

The number of non-germinated legume seeds was also determined. Burr (*Medicago polymorpha L.*) and barrel medics (*Medicago truncatula Gaertn.*), were the most common pasture legumes while clovers such as subterranean (*Trifolium subterraneum L.),* balansa (*Trifolium michelianum Savi.)* and rose (*Trifolium hirtum All.)* clover formed only a small portion on most farms. Only seven of the farms generated more than 300 legume seedlings m-2. A positive correlation was derived between the number of legume seeds and seedlings. This finding emphasised the importance of maintaining adequate legume seed reserves in the soil. Negative correlations were derived between weed and legume seedling populations. This finding indicated that inadequate weed control possibly limited pasture productivity on the farms.
Keywords: *Trifolium species, Medicago truncatula, M. polymorpha*, grass weeds, broadleaf weeds.

Introduction

The winter rainfall agro-pastoral area of South Africa is mainly situated within the Western Cape Province. The Western Cape is relatively poor in natural resources and agriculture is one of the most important socio-economic drivers. The main cropping areas of the province, the Swartland, Rûens and Overberg, receive on average 300 to 500 mm of predominantly (70 to 90%) winter (April/May to September/October) rainfall per annum. The region has an estimated 2 500 000 ha of cultivated land with mainly shallow, stony shale soils, of which approximately 600 000 ha are utilised for legume pastures (1989, Unpublished report by Western Cape Department of Agriculture). These pastures are mainly grazed by sheep, for wool and mutton production, but also by increasing numbers of beef and dairy cattle.

The pastures are rotated with crops such as wheat (*Triticum aestivum L.),* barley (*Hordeum vulgare L.)* and canola (*Brassica napus L.).* The major portion of the Overberg and Rûens is planted to longer phase (> five seasons) lucerne pastures (*Medicago sativa L.)* which is usually followed by approximately five consecutive cropping seasons. However, in the Swartland and the Overberg and Rûens pasture-crop rotation systems with one season of self-regenerating pasture legumes, such as annual medics and clover, followed by one season of crop are, are also used. Medics such as barrel *(Medicago truncatula Gaertn.)* and burr (M. polymorpha L.) medic dominate these pastures, but clovers such as balansa (*Trifolium michelianum Savi.),* subterranean (*T. subterraneum L.)* and rose (*T. hirtum All.)* clover are also used to a more limited extent in some areas. This study will focus on the latter type of pasture.

Legume pastures are important for sustainable crop and animal production in the Western Cape. These pastures fix large quantities of nitrogen which reduce the nitrogen fertilizer needs of subsequent crops (Ladd et al., 1981). Equally important, however, is the fact that grass weeds can be most effectively controlled in the legume pasture phase of such systems. Le Roux, et al. (1995) found an 89% decrease in numbers of grass weed plants in a subsequent wheat crop, a 51% decrease in take-all (*Gaeumannomyces graminins var. tritici*) and a 34% increase in wheat yield when grass weeds are controlled in a previous medic pasture. Similar advantages have been documented in such systems in Australia (MacLeod, et al., 1993). The other important advantages of legumes are the fact that they supply an even distribution of dry matter, alleviating the shortage of dry matter during critical periods, and the positive influence they have on individual animal production, which is important for high animal production (Van Heerden & Tainton, 1987). Legume based pastures outyield grass dominant pastures in terms of animal products (Van Heerden, et al., 1989, Nicol & Edwards, 2011). The control of grass weeds in dryland medic pastures also has a positive influence on medic pod production and sustainability (Van Heerden, 1990). The successful implementation of the legume pasture-crop system is made possible by the use of self regenerating annual pasture legumes which are able to survive one or two cropping seasons, between pasture phases (Carter, 1987).

These legumes produce a large number of seeds at the end of each growing season and most of the seeds break dormancy during late summer and early autumn only after one or more seasons in or on top of the soil. Farmers and advisors have reported a decrease in the productivity of annual legume pastures on commercial farms A similar decline in the productivity of annual legume pastures in the southern Australian agro-pastoral zone was found to be due to a decrease in the number of legume seedlings re-establishing after the crop phase (Carter et al., 1982; Gillespie, 1983).

Gillespie (1983) also attributed the deterioration of subterranean clover pastures in Australia to changes in winter rainfall characteristics, increased cropping frequency and longer cropping phases, changing crop and pasture management practices, poor grazing management and increased incidence of diseases and insect pests. Carter (1987) implicated the same factors with medic pasture rundown in Australia. The common reason for the failure of legume pastures in the Australian cereal belt has been found to be inadequate seed reserves and consequent low seedling density (Carter & Porter, 1993).

According to Carter & Porter (1993) the major constraints are also inadequate control of insect pests, the inadequate control of summer-autumn grazing of medic pods and clover burrs (especially on very hard setting soils) and the inadequate control of the depth of tillage. Kotzé, et al. (1998) also found at Riviersonderend in the Rûens that deep cultivation, during the cropping phase, depressed medic seedling regeneration. The proportion of ingested medic seed voided in sheep faeces differ between species and cultivars. Kotzé, et al. (1995) found that burr medic was superior to barrel medic in this regard and that sheep voided 23% of ingested burr medic seeds, but only 4% of barrel medic seeds. According to Reed, et al. (1989) the persistence of self-regenerating annual legumes within distinctly winter rainfall climates is also determined by factors such as seed production, seed conservation and adaptation. A survey was conducted in order to try and quantify the legume seedling regeneration potential and residual (non-germinating) seed levels and grass and broad leaf weed seedling numbers within annual legume pastures in commercial crop-pasture systems. This survey was conducted on 30 farms in the Western Cape region of South Africa.

Materials and Methods

A total of 114 randomly selected paddocks were sampled on 30 commercial farms distributed through the Swartland (22 farms), Rûens and Overberg (8 farms) regions, during February to April over a period stretching from 1998 to 2004. Four to six paddocks were randomly selected per farm, originally established with mixtures of barrel and burr medic cultivars and, in a few cases, subterranean, rose and balansa clover. The pastures were originally established between five and ten years ago and were all part of one year pasture and one year crop systems and were sampled after the crop phase.

The top 50 mm of the soil was sampled with the aid of 100 mm long round steel tubes with a sampling area of 0.066 m^2. A total of 12 samples were randomly taken within each paddock. Paddock sizes were on average between 30 and 50 ha. The samples were moved to a water cooled greenhouse, placed in two liter (220 x 150 x 75 mm) well drained plastic containers. The samples were wetted immediately after collection and daily thereafter and the seedlings were allowed to establish at 15 to 18 ^{o}C night and 20 to 25 ^{o}C day temperatures, which approximates the average late autumn/early winter temperature regime of the region, for three to four weeks.

Seedlings of each legume species were identified and counted. The weed seedlings were categorised into grass and broadleaf weeds and also counted. Subsequently the non-germinated legume seeds remaining in each soil sample were extracted by hand sorting and counted, after removing the soil by washing and then drying the samples. Non-germinated seeds were visually categorised into barrel and burr medic and clover seeds. The data was expressed as number m-2 by multiplying with a factor. The viability of the non-germinated seeds was not tested and no field seedling counts were done. Soil samples of each sample site were analysed. The pH, salinity, P, K, Cu, Mn and Zn content of these samples were determined. The farms were compared for legume seed and seedling and weed seedling numbers, using individual paddocks (between four and six) as replicates and a least squares statistical method (Draper and Smith, 1966).

Results and Discussion

The total number of legume seedlings (Table 1a and 1b) varied between 26 and 758 seedlings m^{-2}, the total medic seedling varied between 5 and 725 seedlings m-2 and the total clover seedlings between 0 and 246 seedlings m^{-2}. Previous research has shown that legume seedling numbers of more than 600 seedlings m^{-2} are ideal, while 200 to 300 seedlings m^{-2} seems to be the minimum acceptable level (van Heerden, unpublished data). According to this norm only seven of the farms had sufficient numbers of total legume seedlings.

Medics on average formed the main component (86.3%) of the legume seedlings. The average number of burr medic seedlings (49.3%) tended to be higher than that of barrel (37.6%) medics, although only 13 farms had more burr than barrel medic seedlings. Although not significantly so ($P < 0.05$), the proportion of barrel medic seedlings tended to be higher on the Rûens and Overberg (44.4%), than the Swartland (21.0%) farms. There seems to be a greater variation between farms and paddocks in the seedling numbers of the burr than the barrel medics. The average number of clover seedlings (13.6%) was lower and only three farms had more than 100 clover seedlings m^{-2}, which consisted of subterranean, balansa and rose clover.

The grass and broadleaf weed seedling count varied significantly ($P < 0.05$) between farms. The grass weed seedling count varied from 2 grass seedlings m^{-2} to 946 seedlings m^{-2}. On average the number of broadleaf weed seedlings (67.5% of total weed seedlings) tended to be higher than that of the grass seedlings. However, ten farms, of which eight were in the Swartland, had more grass than broad leaf weeds. Pieterse (2008) found that the resistance of both grass and broadleaf weeds to chemical herbicides, used in the pasture and crop phases, was becoming an ever greater problem. In the light of these findings it is interesting to note that grasses seem to be more effectively controlled chemically in these systems than broadleaf weeds. This seems to indicate that broadleaf weeds are more of a problem than grasses in the pasture phase of most of the farms. This is in accordance with observations made by farmers and advisors.

Farm	Region	Legumes (number m^{-2})			Weeds (number m^{-2})		
		Medic Total	Clover Total	Total Legumes	Grass	Broad Leaf	Total Weeds
1	Swartland	4.5 ^{d}	47.9 ^{ab}	52.4 ^{f}	531.8 ^{abcd}	488.3 ^{de}	1020.1 ^{bcdef}
2	Swartland	31.5 ^{cd}	0.0 ^{b}	31.5 ^{f}	161.5 ^{cdef}	1598.5 ^{a}	1760.0 ^{abc}
3	Swartland	56.3 ^{cd}	9.2 ^{b}	65.5 ^{def}	37.0 ^{f}	1205.3 ^{ab}	1242.3 ^{abcde}
4	Swartland	39.1 ^{cd}	0.0 ^{b}	39.1 ^{ef}	318.6 ^{cdef}	106.0 ^{de}	424.6 ^{def}
5	Swartland	31.1 ^{cd}	0.0 ^{b}	31.1 ^{f}	179.1 ^{cdef}	645.1 ^{bcde}	824.2 ^{cdef}
6	Swartland	24.0 ^{d}	2.3 ^{b}	26.3 ^{f}	206.9 ^{cdef}	378.5 ^{de}	585.4 ^{def}
7	Swartland	45.4 ^{cd}	17.7 ^{b}	63.1 ^{ef}	89.6 ^{def}	364.6 $_{de}$	454.2 ^{def}
8	Swartland	58.0 ^{cd}	119.5 ^{ab}	177.5 ^{def}	401.8 abcdef	331.8 ^{de}	733.6 ^{def}
9	Swartland	122.3 ^{cd}	0.0 ^{b}	122.3 ^{def}	188.7 ^{cdef}	524.1 ^{cde}	712.8 ^{def}
10	Swartland	26.5 ^{d}	4.8 ^{b}	31.3 ^{f}	61.2 ^{ef}	1132.9 ^{abc}	1194.1 ^{bcde}
11	Swartland	84.5 ^{cd}	245.8 ^{ab}	330.3 ^{cdef}	555.4 ^{abc}	651.8 ^{bcde}	1207.2 ^{bcde}
12	Swartland	82.0 ^{cd}	2.5 ^{b}	84.5 ^{def}	232.1 ^{cdef}	534.9 ^{cde}	767.0 ^{cdef}
13	Swartland	64.3 ^{cd}	37.9 ^{ab}	102.2 ^{def}	214.5 ^{cdef}	1731.0 ^{a}	1945.5 ^{ab}
14	Rûens & Overberg	62.2 ^{cd}	9.2 ^{b}	71.4 ^{def}	170.7 ^{cdef}	467.6 ^{de}	638.3 ^{def}
15	Rûens & Overberg	235.5 ^{bcd}	0.8 ^{b}	236.3 ^{cdef}	1.7 ^{f}	91.7 ^{de}	93.4 ^{f}
16	Rûens & Overberg	100.1 ^{cd}	0.8 ^{b}	100.9 ^{def}	41.2 ^{f}	667.0 ^{bcd}	708.2 ^{def}
17	Rûens & Overberg	120.5 ^{cd}	0.0 ^{b}	120.5 ^{def}	184.8 ^{cdef}	264.9 ^{de}	449.7 ^{def}
18	Rûens & Overberg	133.7 ^{cd}	10.3 ^{b}	144.0 ^{def}	788.5 ^{ab}	614.4 ^{bcde}	1402.9 ^{abcd}
19	Rûens & Overberg	110.2 ^{cd}	28.0 ^{ab}	138.2 ^{def}	68.1 ^{ef}	116.4 ^{de}	184.5 ^{f}
20	Swartland	214.4 ^{bcd}	7.9 ^{ab}	222.3 ^{cde}	306.6 ^{cdef}	213.9 ^{de}	520.5 ^{def}
21	Rûens & Overberg	357.0 ^{bc}	0.0 ^{b}	357.0 ^{cd}	77.0 ^{def}	160.2 ^{de}	237.2 ^{ef}
22	Rûens & Overberg	293.3 ^{bcd}	0.0 ^{b}	293.3 ^{cdef}	14.2 ^{f}	76.7 ^{de}	90.9 ^{f}
23	Rûens & Overberg	226.3 ^{bcd}	83.0 ^{ab}	309.3 ^{cdef}	500.5 ^{abcde}	1708.7 ^{a}	2209.2 ^{a}
24	Swartland	211.3 ^{bcd}	134.5 ^{a}	345.8 ^{cdef}	945.6 ^{a}	153.9 ^{de}	1099.5 ^{bcdef}
25	Swartland	163.6 ^{cd}	1.2 ^{b}	164.8 ^{def}	178.5 ^{cdef}	31.4 ^{de}	209.9 ^{f}
26	Swartland	249.8 ^{bcd}	6.1 ^{b}	255.9 ^{cdef}	189.2 ^{cdef}	152.4 ^{de}	341.6 ^{ef}
27	Swartland	247.9 ^{bcd}	3.8 ^{b}	251.7 ^{cdef}	162.8 ^{cdef}	212.6 ^{de}	375.4 ^{ef}
28	Swartland	503.0 ^{ab}	4.2 ^{b}	507.2 ^{bc}	259.1 ^{cdef}	221.2 ^{de}	480.3 ^{def}
29	Rûens & Overberg	725.4 ^{a}	0.0 ^{b}	725.4 ^{ab}	115.4 ^{cdef}	43.5 ^{de}	158.9 ^{f}
30	Swartland	698.4 ^{a}	59.5 ^{ab}	757.9 ^{a}	28.6 ^{f}	53.3 ^{de}	81.9 ^{f}
Average		**177.4**	**27.9**	**205.3**	**240.4**	**498.1**	**738.4**

Table 1a - Average number of medic, clover, total legume, grass, broad leaf weed and total weed seedlings m^{-2} on the 30 farms sampled

Farm	Region	Medics (number m^{-2})			Clover (number m^{-2})			
		Barrel	Burr	Total	Rose	Bal-ansa	Sub-Terranean	Total
1	Swartland	3.2^{f**}	1.3^{d}	4.5^{d}	33.4^{a}	2.5^{b}	12.0^{b}	47.9^{ab}
2	Swartland	26.5^{ef}	5.0^{d}	31.5^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
3	Swartland	39.5^{cdef}	16.8^{d}	56.3^{cd}	0.8^{b}	0.0^{b}	8.4^{b}	9.2^{b}
4	Swartland	24.6^{ef}	14.5^{d}	39.1^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
5	Swartland	26.9^{ef}	4.2^{d}	31.1^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
6	Swartland	21.5^{ef}	2.5^{d}	24.0^{d}	0.0^{b}	2.3^{b}	0.0^{b}	2.3^{b}
7	Swartland	29.0^{ef}	16.4^{d}	45.4^{cd}	3.8^{b}	2.5^{b}	11.4^{b}	17.7^{b}
8	Swartland	29.0^{ef}	29.0^{d}	58.0^{cd}	0.0^{b}	4.7^{ab}	114.8^{ab}	119.5^{ab}
9	Swartland	92.0^{cdef}	30.3^{d}	122.3^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
10	Swartland	24.0^{ef}	2.5^{d}	26.5^{d}	0.0^{b}	4.8^{b}	0.0^{b}	4.8^{b}
11	Swartland	84.5^{cdef}	0.0^{d}	84.5^{cd}	35.1^{a}	5.9^{ab}	204.8^{a}	245.8^{ab}
12	Swartland	82.0^{cdef}	0.0^{d}	82.0^{cd}	0.0^{b}	2.5^{b}	0.0^{b}	2.5^{b}
13	Swartland	49.2^{cdef}	15.1^{d}	64.3^{cd}	0.0^{b}	0.0^{b}	37.9^{b}	37.9^{ab}
14	Rûens & Overberg	0.0^{f}	62.2^{d}	62.2^{cd}	4.2^{b}	5.0^{b}	0.0^{b}	9.2^{b}
15	Rûens & Overberg	84.1^{cdef}	151.4^{cd}	235.5^{bcd}	0.0^{b}	0.8^{b}	0.0^{b}	0.8^{b}
16	Rûens & Overberg	35.3^{def}	64.8^{d}	100.1^{cd}	0.0^{b}	0.8^{b}	0.0^{b}	0.8^{b}
17	Rûens & Overberg	60.6^{cdef}	59.9^{d}	120.5^{cd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
18	Rûens & Overberg	63.1^{cdef}	70.6^{d}	133.7^{cd}	1.3^{b}	6.5^{ab}	2.5^{b}	10.3^{b}
19	Rûens & Overberg	83.1^{cdef}	27.1^{d}	110.2^{cd}	1.3^{b}	7.0^{ab}	19.7^{b}	28.0^{ab}
20	Swartland	152.0^{abcd}	62.4^{d}	214.4^{bcd}	0.6^{b}	6.7^{ab}	0.6^{b}	7.9^{ab}
21	Rûens & Overberg	117.3^{cdef}	239.7^{bcd}	357.0^{bc}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
22	Rûens & Overberg	253.6^{ab}	39.7^{d}	293.3^{bcd}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
23	Rûens & Overberg	81.2^{cdef}	145.1^{cd}	226.3^{bcd}	5.9^{b}	4.8^{ab}	72.3^{ab}	83.0^{ab}
24	Swartland	160.2^{abc}	51.1^{d}	211.3^{bcd}	0.6^{b}	4.6^{a}	129.3^{ab}	134.5^{a}
25	Swartland	22.1^{ef}	141.5^{cd}	163.6^{cd}	0.0^{b}	1.2^{b}	0.0^{b}	1.2^{b}
26	Swartland	111.0^{cdef}	138.8^{cd}	249.8^{bcd}	0.0^{b}	6.1^{b}	0.0^{b}	6.1^{b}
27	Swartland	140.0^{bcde}	107.9^{cd}	247.9^{bcd}	0.0^{b}	3.8^{b}	0.0^{b}	3.8^{b}
28	Swartland	107.7^{cdef}	395.3^{abc}	503.0^{ab}	0.0^{b}	3.4^{b}	0.8^{b}	4.2^{b}
29	Rûens & Overberg	272.5^{a}	452.9^{ab}	725.4^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}
30	Swartland	24.7^{ef}	673.7^{a}	698.4^{a}	12.1^{ab}	5.6^{ab}	41.8^{b}	59.5^{ab}
Average		**76.7**	**100.7**	**177.4**	**3.3**	**2.7**	**21.9**	**27.9**

Table 1b - Average number of medic, clover, total legume, grass, broad leaf weed and total weed seedlings m^{-2} on the 30 farms sampled

Farm	Region	Medic (number m^{-2})			Total clover (number m^{-2})	Total legume (number m^{-2})
		Barrel	Burr	Total		
1	Swartland	7.6 ^{g*}	6.1 ^{b}	12.1 ^{b}	242. ^{b}	36.3 ^{b}
2	Swartland	48.4 ^{g}	0.0 ^{b}	48.4 ^{b}	0.0 ^{b}	48.4 ^{b}
3	Swartland	87.8 ^{efg}	27.3 ^{b}	115.1 ^{b}	9.1 ^{b}	124.1 ^{b}
4	Swartland	92.4 ^{defg}	75.7 ^{b}	168.0 ^{b}	0.0 ^{b}	168.0 ^{b}
5	Swartland	101.4 ^{defg}	95.4 ^{b}	198.3 ^{b}	0.0 ^{b}	198.3 ^{b}
6	Swartland	246.8 ^{cdefg}	93.9 ^{b}	339.1 ^{b}	0.0 ^{b}	339.1 ^{b}
7	Swartland	375.5 ^{bcdefg}	84.8 ^{b}	460.2 ^{b}	13.6 ^{b}	473.9 ^{b}
8	Swartland	131.7 ^{cdefg}	63.6 ^{b}	195.3 ^{b}	230.1 ^{b}	423.9 ^{b}
9	Swartland	246.8 ^{cdefg}	198.3 ^{b}	446.6 ^{b}	0.0 ^{b}	446.6 ^{b}
10	Swartland	508.7 ^{bcd}	22.7 ^{b}	531.4 ^{b}	0.0 ^{b}	531.4 ^{b}
11	Swartland	230.1 ^{cdefg}	1.5 ^{b}	231.6 ^{b}	125.7 ^{b}	357.3 ^{b}
12	Swartland	504.1 ^{bcde}	7.6 ^{b}	511.7 ^{b}	0.0 ^{b}	511.7 ^{b}
13	Swartland	528.4 ^{bc}	6.1 ^{b}	534.4 ^{b}	4.5 ^{b}	540.5 ^{b}
14	Rûens & Overberg	101.4 ^{defg}	505.7 ^{b}	607.1 ^{b}	1.5 ^{b}	608.6 ^{b}
15	Rûens & Overberg	115.1 ^{cdefg}	345.2 ^{b}	460.2 ^{b}	0.0 ^{b}	460.2 ^{b}
16	Rûens & Overberg	210.4 ^{cdefg}	372.4 ^{b}	582.9 ^{b}	0.0 ^{b}	582.9 ^{b}
17	Rûens & Overberg	366.4 ^{bcdefg}	295.2 ^{b}	660.1 ^{b}	0.0 ^{b}	660.1 ^{b}
18	Rûens & Overberg	192.3 ^{cdefg}	430.0 ^{b}	622.2 ^{b}	1.5 ^{b}	623.8 ^{b}
19	Rûens & Overberg	160.5 ^{cdefg}	520.8 ^{b}	679.8 ^{b}	39.4 ^{b}	720.6 ^{b}
20	Swartland	327.0 ^{cdefg}	222.6 ^{b}	549.6 ^{b}	1.5 ^{b}	551.1 ^{b}
21	Rûens & Overberg	219.5 ^{cdefg}	370.9 ^{b}	590.4 ^{b}	0.0 ^{b}	590.4 ^{b}
22	Rûens & Overberg	996.2 ^{a}	0.0 ^{b}	996.2 ^{b}	0.0 ^{b}	996.2 ^{b}
23	Rûens & Overberg	317.9 ^{cdefg}	449.6 ^{b}	767.6 ^{b}	28.8 ^{b}	796.3 ^{b}
24	Swartland	221.0 ^{cdefg}	455.7 ^{b}	676.7 ^{b}	239.2 ^{b}	915.9 ^{b}
25	Swartland	383.0 ^{bcdefg}	714.6 ^{b}	1097.6 ^{b}	0.0 ^{b}	1097.6 ^{b}
26	Swartland	487.5 ^{bcdef}	598.0 ^{b}	1085.5 ^{b}	0.0 ^{b}	1085.5 ^{b}
27	Swartland	779.7 ^{ab}	407.3 ^{b}	1186.5 ^{b}	0.0 ^{b}	1186.9 ^{b}
28	Swartland	207.4 ^{cdefg}	905.3 ^{b}	1112.8 ^{b}	0.0 ^{b}	1112.8 ^{b}
29	Rûens & Overberg	510.2 ^{bcd}	1090.1 ^{b}	1600.3 ^{b}	0.0 ^{b}	1600.3 ^{ab}
30	Swartland	68.1 ^{fg}	3465.5 ^{b}	3532.1 ^{b}	43.9 ^{b}	3576.0 ^{a}
Average		**292.4**	**394.4**	**686.7**	**25.4**	**712.2**

Table 2. Average number of non-germinated legume seeds m^{-2} on the 30 farms

The average number of non-germinated medic seeds in the soils (687 m^{-2}) was higher than the number of medic seedlings (177 m-2) and implied that 20.5% of the total medic (seedlings plus non-germinated seed) seed reserve established as seedlings. This proportion was very similar for burr (20.4%) and barrel (20.9%) medics. In the case of the clovers the non-germinated seed (25 m^{-2}) and seedlings (28 m^{-2}) numbers were very similar and 52.8% of the total clover seed reserve established as seedlings. Clover seed was therefore less dormant than the medic seed. This is probably and important factor limiting clover seedling numbers. As in the case of the seedling numbers, the number of non-germinated legume seeds varied significantly ($P < 0.05$) between farms. Soil sampled on farm 30 had the highest number of non-germinated legume seeds (3 576 m-2) while farm 1 had the lowest number (36 m^{-2}). The average number of non-germinated seeds for barrel medic varied between 8 and 996 m^{-2}, for burr medic between 0 and 3466 m^{-2} and for total clovers between 0 and 239 m^{-2}. On average burr medic seeds formed 55.3% of the total number of non-germinated legume seeds, barrel medics 41.0% and clovers only 3.5%. The greater number of non-germinated burr than barrel medic seeds seems to support the research of Kotze, et al. (1995), which showed that a smaller proportion of burr than barrel medic seed is destroyed when ingested by sheep. The danger of overgrazing medic pods during summer, suggested by Carter & Porter (1993), should thus be less of a problem with burr than barrel medics.

A multiple regression analysis was performed using the factors legume seedling and seed numbers, weed and grass and broad leaved weed seedling numbers, soil analysis parameters using only the data for which soil parameters were determined. The only factors which significantly ($P < 0.05$) correlated with legume seedling numbers were total legume seed content and weed seedling numbers. Using all the data sampled statistical relationships were developed between these three factors. A significantly ($P < 0.05$) positive polynomial relationship was derived between the total number of legume seeds and the number of legume seedlings which had regenerated (Figure 1). This emphasizes the importance of maintaining high residual legume seed reserves to ensure the regeneration of adequate numbers of legume seedlings. This supported the view of Carter & Porter (1993) who stressed the importance of maintaining high seed levels. As a smaller proportion the medic than clover seeds regenerated as viable seedlings the percentage of the seed bank which regenerates each year will therefore be determined by the species composition of the seed bank. It also shows that a much greater seed bank of medic than clover seeds are needed to ensure that adequate numbers of legume seedlings regenerate. On the other hand, clover seed populations should be more vulnerable to adverse conditions such as seasons with a false break during odd years, due to unseasonal late summer rains followed by dry hot weather. Significantly ($P < 0.05$) negative relationships exist between the total number of legume seedlings and the total weed seedling and the broadleaf weed seedling numbers (Figure 2).

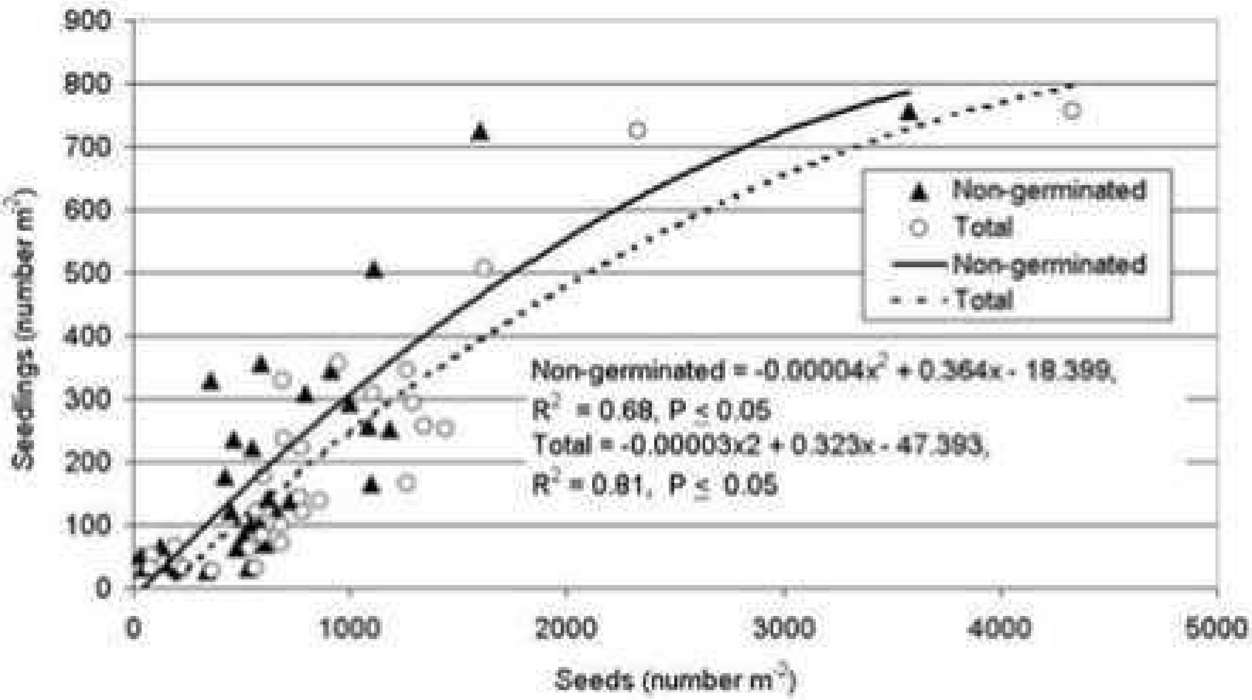

Figure 1. Relationship between the number of non-germinated and total legume seeds and the number of legume seedlings on 30 farms

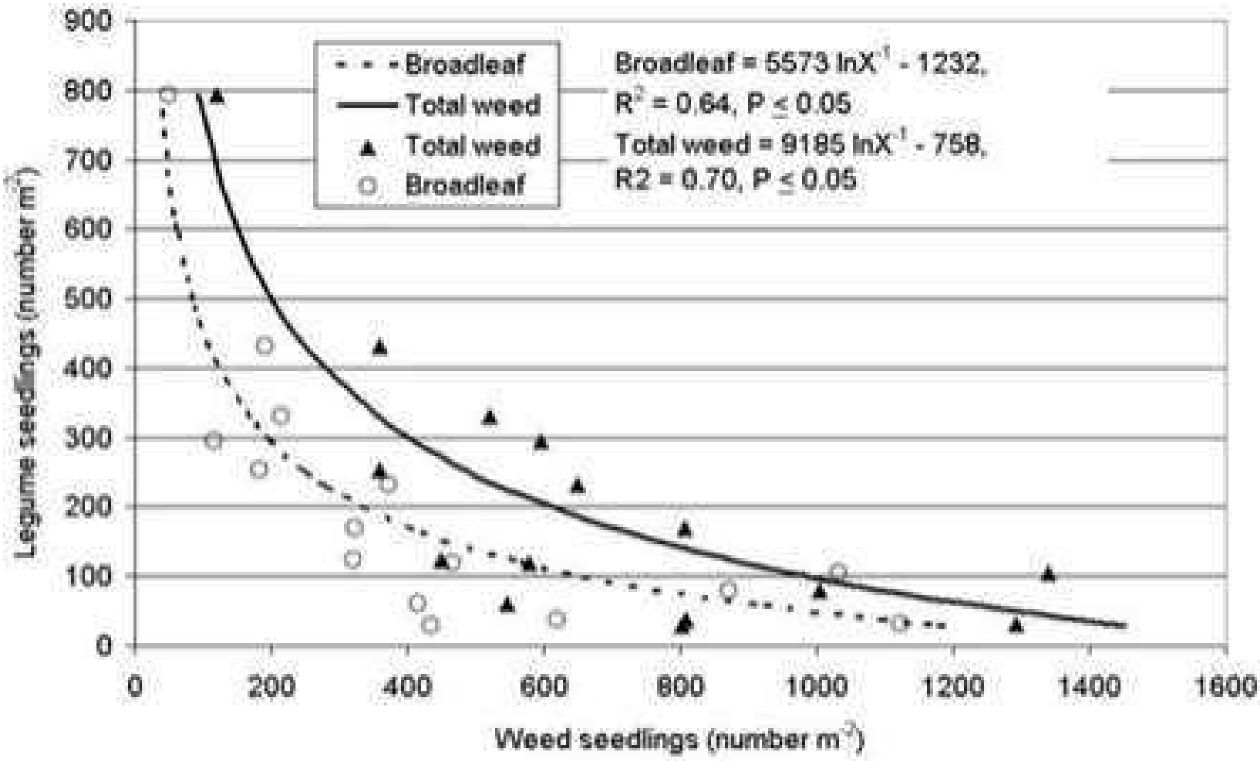

Figure 2. Relationship between the number of broadleaf and total weed seedlings and the number of legume seedlings on 30 farms

No significant relationship was found between the number of grass seedlings and the number of legume seedlings. This can be attributed to the fact that the annual grass weeds were generally effectively controlled by the application of chemical herbicides in the pasture phase of these systems (Le Roux et al., 1995), while it was much more difficult to control broadleaf weeds selectively in this phase. From Figure 2 it seems as if the total weed seedling numbers should ideally be below 100 m-2 in the pasture to ensure maximum legume seedling regeneration.

The data shows that weed infestation may be one of the major factors limiting pasture productivity on commercial farms and can be attributed to the negative influence of weed competition on medic pod and seed production (Van Heerden, 1990). The pastures of farmers who kept weed populations in both their crops and pastures under control, therefore, also had higher numbers of legume seedlings. The increased resistance to the herbicides used in both the pasture and crop phases reported by industry (Pieterse, 2008) may, however, in future result in grass weeds also increasingly becoming a major factor limiting pasture productivity.

Conclusions

The number of legume seedlings which had regenerated in the pastures of most farms (77%), was lower than what is needed to attain high pasture yields. The significant relationships which were derived between legume seed and seedling maintaining high residual legume seed reserves to ensure the regeneration of adequate numbers of legume seedlings. The large difference in legume seedling and non-germinated seed numbers between farms is, however, indicative of a rather serious variance in management practices and the control of broadleaf weeds seem to be the main problem. Farmers are inclined to focus more on weed control during the crop than the pasture phases.

For greater productivity and sustainability of annual legume pastures they should, however, endeavor to also control both grass and broad leaf weeds during the pasture phase. Farmers are reluctant to do this due to the fact that herbicides are expensive and the removal of weeds often reduces grazing capacity. Van Heerden (1990), however, showed that the removal of weeds result in increased medic pod production and improve medic seed reserve levels and thus the sustainability of medic pastures on the long term. The higher proportion of legumes in pastures submitted to adequate weed control should also have a positive influence on individual animal production (Van Heerden & Tainton, 1987, Van Heerden, et al., 1989).

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