Weed Infestation Rate and Effect on the Cultivated Pasture Productivity at University of Fort Hare Dairy Trust, South Africa

Masibonge Gxasheka[1, 3]* Mota Lesoli[2, 3] Bukho Gusha[3] Simthandile Gxasheka[5] Cebisa Kumanda[6] Thobela Louis Tyasi[4]

1. Laboratory of Plant Pathology, Department of Plant Protection, Jilin Agricultural University, Changchun, Jilin 130118, China.
2. Fort Cox College of Agriculture and Forestry, King Williams Town, South Africa
3. Department of Livestock and Pasture Science, University of Fort Hare, Alice, Eastern Cape, South Africa
4. Department of Animal Genetics, Breeding and Reproduction, College of Animal Science and Technology Jilin Agricultural University, Changchun .130118, P. R. China
5. Department of Rural Development and Land Reform, Port Elizabeth, South Africa
6. Department of Animal Nutrition, College of Animal Science and Technology, Jilin Agricultural University, Changchun, 130118, China

* E-mail of the corresponding author: masibongem@yahoo.com

Abstract

Pasture-based dairy farming is widely practised along coastline of South Africa. Cultivated pastures serves as cheapest source of protein for dairy cows of these dairy farms; although, unwanted plants (weeds) reduce their production. Here, we evaluate the weed infestation rate with its effect on the biomass production of the cultivated pasture. Weeds exert a competition which can cause considerable pasture yield reduction. A total of 6 camps were selected for this study. Selection criteria included the presence of weeds on three camps that were previously applied roundup herbicide and three camps that were not applied roundup herbicide. And also, different levels of weed infestation were considered. The application of roundup herbicide did not really affect weed infestation. Thus, indicates that some are resistant to the herbicide. Moreover, high infestation of weeds has a significant effect on the total biomass production. From these findings, nutritional analysis of these weeds would be necessary to examine the quality or condition of weeds in terms toxicity levels. Thus, also test out whether those weeds contribute on the total biomass does not have smell on the feed that could affect feed intake or quality of the milk.

Key words: Weeds infestation, cultivated pastures, Weed density

1. Introduction

1.1. Background

Pasture-based dairy farming is widely practised along coastline (Western Cape, Eastern Cape and KwaZulu-Natal) of South Africa. The dairy industry is the fourth largest agricultural industry in South Africa, representing 5.6% of the gross value of all agricultural production (Mkhabela and Mndeme, 2010). However, cultivated pastures that serves as cheapest source of protein for dairy cows are affected by unwanted plants (weeds). These weeds can be defined as wild plants that grow where they are not needed and in competition with the desirable plants (cultivated pastures) (Singh *et al.,* 2011; Bridges, 1994).

Previously conducted studies reveals that high infestation rate of weeds directly affect production of desirable plants through competition for nutrients, moisture, water, sunlight and space, which eventually reduce their productive capacity (Randall, 1996; Abaye *et al.,* 2009; Al-Tawaha *et al.,* 2008; Celebi1*et al.,* 2010; De Bruijn et al., 2010; Olson and Lacey, 1994). Robert et al. (2003) also point out that weeds can compete directly with forage grasses to reduce their nutritional value and longevity (Robert *et al.,* 2003). Moreover, these plants can even replace desirable grass species, filling in gaps or voids and reducing yield and overall quality of pasture and forages (Fuhlendorf *et al*., 2009; Al-Tawaha *et al.,* 2008). According to Thomas *et al* (1994), biennial and perennial weeds pose the biggest problem for pasture producers due to the fact that biennials and perennials produce seed each year and have a potential to start new infestations. Perennial weeds such as tall ironweed (*Vernonia altissima*), Canada thistle (*Cirsium arvense*), and multiflora rose (*Rosa multiflora*) reproduce from underground roots or rhizomes (Harker *et al*., 2000). Perennial rooting structures can survive for several years in the soil and are often unaffected by occasional mowing or livestock grazing (Gerlach *et al*., 1998).

Nonetheless, several weeds species in the semi-arid pastures are well grazed by animals and some may even be preferred to be planted as cultivated pasture species (Tainton, 2000; Olson and Lacey, 1994). However, level of weed infestation can trigger acceptability of palatable weeds. For example, when the infestation rate is low, and thus, it may not be essential to implement any control measures (Edwards, 1989). In contrast, a serious concern begins when taller weeds become prominent with high infestation rate in such way that desirable plant are subjected to extreme shading (Tainton, 2000). Moreover, dry conditions also automatically forces weeds to compete strongly for moisture. Therefore, management of weeds is an essential component of pasture-based systems and the use of herbicides is one of the most common methods and even used in the cropping systems (Jones *et al.,* 2009). The extent to control weeds largely depend on the ultimate purpose of the pasture and the urgency with which the pasture needs to be brought into full production (Abdin *et al.,* 2000). The management of weeds is crucial for maintaining the productivity of cultivated pastures. Jones and Medd, (2000) indicated that, pasture invading weed species should be assessed for their competitive ability (their potential to reduce desirable forage species). The objectives of this study were therefore to investigate 1) the effect of weed infestation on cultivated pastures plants density, 2) the relationship between weed density on cultivated pasture plant density and biomass production 3) and also identify species of weeds growing on cultivated pastures.

2. Material and Methods

2.1. Description of study area

The study was conducted at the University of Fort Hare Dairy Trust farm located in Alice which is 120 km from East London along the eastern coastline. The geographical location of the farm is 32.8º S and 26.9º E and lies 520 m above sea level. The area is generally flat and the soils are mostly shale and mudstone derived. Approximately 200 ha of the farm is divided into 36 paddocks, covered by high yielding perennial rye grass (*Lolium multiflorum* intersown)with clover cultivar (*Trifolium repens*) at a ratio of 4 : 1. The average annual rainfall is 480 mm and most of it is received in hot-wet season (September to April). The mean annual temperature of the farm is 18.7◦C. The hot-wet season is characterized by hot sunny weather and thunderstorms with average temperature range of 17 ◦C to 28 ◦C. The post-rain season is characterized by little rainfall and warm weather. The cool dry season is characterized by moderate weather with average temperature range of 8 ◦C to 20 ◦C. The hot-dry season is characterized by warming temperatures. The farm is situated on the Bisho thornveld (Mucina and Rutherford, 2006). The vegetation around the farm includes threes such as *Acacia karroo* dominating, and grass such as *Themeda triandra, Panicum maximum* and *Erogrostis* species.

2.2. Experimental design

A total of 6 camps were selected for this study. Selection criteria included the presence of weeds on three camps that were previously applied roundup herbicide and three camps that were not applied roundup herbicide. The camps were also selected to have adjacent sites with light (5-15%), moderate (>15-35%) and heavy weed infestation (>35%) cover. Three plots (replicates) of 50 m x 50 m were randomly marked at each infestation level. The average distance between the plots was 10 m. Within each plot, three transect of 100 m were marked to record grass and weed data.

2.3. Data collection

Five 0.5 m x 0.5 m (0.25m^2) quadrants were systematically laid along transect on the interval of 10 m. All grass and weed species within each quadrant were recorded; their tuft diameter and distance between any two tufts were measured for plant density. Each species was then cut separately and placed in paper bags. Collected samples of grass and weeds were taken to the laboratory and oven dried at 60°c for 48 hours to determine the dry matter biomass.

2.4. Data analysis

SPSS (1999) was used to analyse the data. One way ANOVA was used to determine the difference between the treatments for weed infestation rate and weed biomass contribution on the total forage biomass. All the analysis was considered significant at $p < 0.05$. Correlation analysis was used to test the relationship between the plant density and biomass. All the analysis was considered significant at $p < 0.05$.

3. Results

3.1. Effect of weed density on intended pasture species density

3.1.1. Relationship between the intended pasture plants and weeds densities

Perennial rye grass (*Lollium perenne*) was significantly higher ($p < 0.05$) on the camps where roundup herbicide was not applied (50.5%) than on the camps where the herbicide was applied (44.5%). The *Erigeron floribundus* was significantly higher ($p < 0.05$) on the applied (0.8%) camps with roundup herbicide than on the non-herbicide applied camps (0.1%). *Plantango lanceolata* was significantly higher ($p < 0.05$) on the camps where the herbicide was applied (4.7%) than the non-applied camps (0.8%). *Cnicus benedictus* was significantly higher ($p < 0.05$) where roundup herbicide was applied (2.7%) compared to the non-herbicide camps (1.1%). The total plant density was significantly higher ($p < 0.05$) on none applied (70.1%) camps than the herbicide applied camps (50.4%). Table 3.1 illustrates the proportions of weeds to rye grass densities.

Table 3.1: Effect (Means percentages ± SE) of Roundup herbicide on the pasture plant and weed density (%/m^2)

	Rye grass	*E. floribundus*	*P. lanceolata*	*C. benedictus*	Total plant density
Applied	44.5±1.5	0.8±0.3	4.7±1.0	2.7±0.4	50.4±1.1
Non-Applied	50.5±2.4	0.1± 0.1	0.8±5.2	1.1±0.2	70.1±2.7

Means are significant at $p < 0.05$

3.1.2. Proportion pasture plant densities and weed species composition at different infestation rate

Rye grass was significantly higher ($p < 0.05$) on the Low weed infested (LWI) (56.2%) camps than Moderate weed infested (MWI) (45.9%) and High weed infested (HWI) (40.3%) camps. *Trifolium repens* (White clover) was significantly higher ($p < 0.05$) on the MWI (45.1%) camps compared to the HWI (23.2%) and LWI (37.2%) camps. *Cotula australis* was significantly higher ($p < 0.05$) on the HWI (6.9%) camps than both the LWI (1.3%) and MWI (1.7%) camps. *Lepidium africanum* was significantly higher ($p < 0.05$) on the HWI (13.2%) than the LWI (9.9%) and MWI (2.0%) camps. *Erigeron floribundus* was significantly higher ($P < 0.05$) on the MWI (6.7%) than LWI (0.1%) and HWI (0.2%) camps. *Plantango lanceolata* was significantly higher ($p < 0.05$) on the HWI (7.6%) than the LWI (0.7%) and MWI (0.0%) camps. The total plant density was significantly higher ($p < 0.05$) on the HWI (75.5%) than both LWI (57.7%) and MWI (48.9%) camps. The total weed density was significantly higher ($p < 0.05$) on the HWI (32.9%) than LWI (6.2%) and MWI (7.7%) camps.

Table 3.2: The Effect (Means percentages ± SE) of weeds infestation on the pasture plant density (%/m^2)

	Rye grass	*White clover*	*C. australis*	*L. africanum*	*E. floribundus*	*P. lanceolata*	Total p. density	Weed density
High	40.3±2.5	23.2±2.0	6.9±1.2	13.2±2.2	0.2±0.2	7.6±1.5	75.5±2.9	32.9±2.8
Moderate	45.9±2.3	45.1±2.1	1.7±0.6	2.0±0.66	6.7±0.1	0.0±0.0	48.9±1.8	7.7±1.3
Low	56.2±2.2	37.2±2.1	1.3±0.4	9.9±0.10	0.1±0.4	0.7±0.4	57.7±2.5	6.2±1.2

Means are significant at $p < 0.05$

3.2. Effects of weed infestation on forage biomass production

3.2.1. Effect of herbicide on weed biomass production

Cotula australis was significantly higher ($p < 0.05$) on the camps where the herbicide was not applied (2.5%) compared to camps where it was applied (0.3%). *Arctotheca calendula* was significantly higher ($p < 0.05$) on the camps where the herbicide was not applied (0.6%) compared to the camps where it was applied (0.4%). *Plantango lanceolata* was significantly higher ($p < 0.05$) on the camps where Roundup herbicide was applied (8.3%) than on the camps where it was not applied (0.6%). *Cnicus benedictus* was significantly higher ($p < 0.05$) on the camps where the herbicide was applied (17.2%) compared to camps where it was not applied (8.5%). The total forage biomass was significantly higher ($p < 0.05$) on the camps where herbicide was not applied (98.1%) compared to the camps where it was applied (72.5%).

Table 3.3.The effect (Mean percentage biomass±SE) of roundup herbicide on the weed Biomass production

	C. australis	*A. Calendula*	*P. lanceolata*	*C. benedictus*	Total plant
Applied	0.3±0.36	0.4±0.21	8.3±1.10	17.2±2.32	72.5±3.75
Non-Applied	2.5±0.77	0.6±0.30	0.6±0.34	8.5±1.43	98.1±6.66

Means are significant at $p < 0.05$

3.2.2. Weed biomass production between infestation rates

The biomass of Rye grass was significantly higher ($p < 0.05$) on the LWI (71.3%) than both MWI (42.7%) and HWI (35.1%) camps. The biomass production for White clover was significantly higher ($p < 0.05$) on the MWI (31.6%) than LWI (13.8%) and HWI (11.8%) camps. In terms of proportion weed species of infestation rates, *Cotula australis* was significantly higher ($p < 0.05$) on the HWI (3.9%) than the LWI (0.0%) and MWI (0.5%) camps. *Lepidium africanum* was significantly higher ($p < 0.05$) on the HWI (12.5%) than LWI (0.0%) and MWI (3.8%) camps. *Erigeron floribundus* was significantly higher ($p < 0.05$) on the HWI (0.7%) than LWI (0.0%) and MWI (0.0%) camps. *Plantango lanceolata* was significantly higher ($p < 0.05$) on the HWI (11.3%) than LWI (0.7%) and MWI (1.5%) camps. The total plant biomass was significantly higher ($p < 0.05$) on the HWI (105.1%) than LWI (85.7%) and MWI (65.5%) camps.

Table 3.4: The effect (Mean percentage biomass ± SE) of weeds infestation on the Biomass production

	Rye grass	White clover	*C. australis*	*L. africanum*	*E. floribundus*	*P. lanceolata*	Total plant	Total weed
High	35.1±4.0	11.8±2.9	3.9±1.1	12.5±2.6	0.7±0.6	11.3±2.6	105.1±7.3	57.6±6.5
Moderate	42.7±4.4	31.6±4.7	0.5±0.5	3.8±1.44	0.0±0.0	1.5±1.07	65.5±3.8	19.5±3.2
Low	71.3±3.7	13.8±2.6	0.0±0.0	0.0±0.00	0.0±0.0	0.7±0.74	85.7±7.6	16.5±5.6

Means are significant at $p < 0.05$

Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.5, No.10, 2015

Table 3.5: The relationship between plant density and biomass production

		Plant density			**Biomass production**				
		P. aviculare	Total	Weed	Rye Grass	White Clove	*C. australis*	*L. africanum*	*A. Calendula*
Plant density	*P. echioides*	1.0***	0.072*	NS	NS	NS	NS	NS	NS
	S. burchellii		-0.200*	NS	NS	0.161*	NS	NS	NS
	E. australis steinh		NS	0.271**	-0.215**	NS	NS	NS	NS
	Tot. pl. D		1.000	0.352**	NS	-0.165*	0.418**	0.197*	0.198*
	W. D			1.000	-0.360**	-0.207**	0.432**	0.572**	NS
Biomass	R. G-BM				1.000	-0.567**	NS	-0.379**	NS
	WC - BM					1.000	-0.175*	NS	NS
	C. australis BM						1.000	0.146*	NS
	L. africanum BM							1.000	NS

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
Note: Tot.pl.D= Total plant density, W.D. = Weed density, R.G-BM= Rye grass biomass, WC-BM= White clover biomass, NS is non-significance

Table 4.6: The relationship between plant density and biomass production

		Plant density							Biomass production					
		kikuyu	White Clover	C. australis	*L. africanum*	*O. hookeri*	P. *lanceolata*	*S. ilicifolius*	Tot. /ha	Tot. W/ha	*P. echioides*	*O. hookeri*	P. *lanceolata*	*S. ilicifolius*
Plant density	Ryegrass	-0.154*	-0.390**	-0.383**	-0.412**	-0.179*	-0.310**	-0.255**	-0.156*	-0.250**	-0.341**	NS	-0.239**	-0.246**
	kikuyuL	1.000	-0.256**	NS	NS	NS	NS	0.462**	NS	NS	NS	NS	NS	0.359**
	White Clover		1.000	-0.288**	-0.342**	-0.137*	-0.185*	-0.167*	NS	-0.256**	-0.286**	-0.213**	NS	NS
	Cotula australis			1.000	0.268**	0.407**	0.224**	0.320**	0.157*	0.313**	0.423**	0.397**	0.156*	0.308**
	L. africanum				1.000	0.137*	NS	NS	0.201*	0.415**	0.496**	0.191*	NS	NS
	A. Calendula					NS	NS	NS	NS	0.173*	0.214**	NS	NS	NS
	O. hookeri					1.000	NS	0.690**	NS	NS	0.171*	0.744**	NS	0.545**
	P. lanceolata						1.000	NS	NS	0.214**	0.300**	NS	.699**	NS
	S. ilicifolius							1.000	NS	NS	0.155*	0.523**	NS	0.702**
	L. camara								0.348**	0.409**	0.149*	NS	NS	NS
Biomass	*Senecio burchellii*								0.335**	0.342**	NS	NS	NS	NS
	Total /ha								1.000	0.796**	0.391**	NS	NS	NS
	Tot.W/ ha									1.000	0.760**	0.130*	0.237*	NS

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

4. Discussion

The way cultivated pastures are managed can have a major influence on the notable amount of weeds present. Thus, use of roundup herbicide revealed that herbicide affected plant density of desirable specie (rye grass) than unwanted plants (weeds). Mueller-Warrant and Rosato (2002) also observed reduced rye grass density on herbicide treated plots. Therefore, this could be attributed to the effect of herbicide on soil nutrient level and alterations on soil microbial activity (Crouzet *et al.,* 2010; Matarczyk *et al.,* 2002). The current study supported by Matarczyk *et al*. (2002) who indicated that the health of ryegrass was adversely affected by roundup herbicide. The effect of roundup herbicide on the *Erigeron floribundus* was not clearly understood. Therefore, weed species such as *Plantango lanceolata* and *Cnicus benedictus* were high on the camps where the herbicide was applied. This could be due to that fact that these species are resistant to the herbicide and their presence threatens the pasture production. Strandberg *et al.,* (2005) highlighted that all weeds are sensitive to roundup herbicide; however, the susceptibility varies significantly among species and growth stages. Besides, long-term effects of roundup on changes in weed species and on the increase in abundance of tolerant weed, species are poorly known (Puricelli and Tuesca, 2005).

In this study roundup herbicide has reduced the total plant density and affect biomass of species found within the applied camps. Therefore, this suggest that roundup have destructive effect on forage production. Furthermore, weed species contribute lot of biomass in the applied camps. This could be attributed to the fact that weeds recover early than desirable species and compete for survival (Thorn, 1988). The results show that plant density of rye grass was significant low on the high infestation. However, ryegrass at low infestation have high plant density due to the reduction of weed population and increasing the possibility for plants to get more resources (Armin and Asghripour, 2011). Armin and Asghripour (2011) stated that cultivation of varieties with high competitive ability cause weeds to be less competitive. At the high infestation, the dominant weed species included *Cotula australis, Lepidium africanum* and *Plantango lanceolata,* the proportion of these weeds was increasing with an increase on infestation. The reasons for these species to be found at higher density on certain plots could not be explained. Nonetheless, that could be attributed to the less competitive potential of the intended species at higher weed intensity. Weeds infestation varies between the camps in terms of species, densities and biomass production at Fort Hare dairy farm. According to Colbach and Sache, (2001), weeds are not homogeneously distributed in fields, but aggregated in patches because they tend to cluster where the conditions are favourable to propagate and disperse. Weeds can produce high amount of biomass per ha under high infestation which indicate the amount of fertilizer, irrigation, and space utilize by weeds to produce such biomass (Vila *et al.,* 2004).

A strong positive relationship was observed between *Picris echioides* and *Polygonum aviculare,* which indicates that they can grow together and encourage one another. Generally explanations for the relationship of weeds fall into resource complementarity where the different species complement each other in their resource use. The positive relationship between the *Senecio burchellii* and white clover, indicate that *Senecio burchellii* have no effect on white clover. This could be attributed to the fact that white clover is more competitive and suppresses weed growth. The effect of white clover on weeds could be related to the canopy cover, which provides shading to the weeds and reduce their photosynthetic efficiency. Den Hollander *et al.*, (2007) also reported that the competitive effect of white clover was due to the canopy height which indicating that yield reduction was mainly caused by competition for light.

The total plant density was positive related to weed density, which indicates that as the weed density was increasing the total plant density was also increasing. This suggests that weeds contribute more in the plant density. Ryegrass was not severely affected by the density of weeds due the enhanced competitive ability of the ryegrass. This study revealed that maximum canopy height and good density of the desirable species are traits that can reduce dry matter of the weeds. Kikuyu grass (*Pennisetum clandestinum*) is an aggressive perennial grass can blocking out light and reducing the vigor of grass species. Therefore, it was removed from the camps but germination of its seedlings still visible. This study reveals negative relationship between Kikuyu, Rye grass and White clover. Therefore, this shows that these pasture species exhibits the competition between them. This suggests that as another species increases the other decreases. That implies that these species cannot survive together. In general, inter-specific competition among these species was due to the insufficient availability of resource, which triggers the competition (Muller-Scharer, 1996). Ryegrass when at the density high shows good competitive ability against some of the weeds.

Kikuyu has suppressed the growth of many weeds to even the white clover through competition. Chou *et al.*, (1987) reported that Kikuyu grasses are phytotoxic in nature; therefore, most of the weeds including desirable species were suppressed by allelopathic effect of kikuyu, hence the biomass was negatively correlated. In the more general sense, Yu *et al*., (2008) reported that performance and inter-species population balance of ryegrass to white clover pastures is affected by aspect of management factors such as defoliation intensity. Most of the weeds do not really compete among each other and indicated by positive linear relationship of these weeds.

Legumes can improve soil quality and benefit subsequent desirable species; hence ryegrass when combine with legume species becomes so competitive among weeds. However, Ross *et al.,* (2001) indicated that weed suppression by clovers tend to be greater on the low-productivity site. When soil fertile is low, weeds does not have strong competitive effect, hence legumes species tend to grow fast than weeds and suppress them. Weeds have greater contribution of biomass production in the Fort Hare dairy farm. The growth suppression of white clover plants and ryegrass plants by weeds was probability through shading and extraction of more soil water (Goh and Bruce, 2005). However, soil disturbance, soil fertility, and propagule supply, can also affect weed invasion at pasture scales (Tracy and Sanderson, 2004).

5. Conclusion and Recommendations

The study showed that weeds affect the plant density of the desirable species in such a way that they increase with the increase with the plant density. Weeds such as *L. africanum, P. lanceolata*, and *E. floribundus* were found to be the most dominating species, which shows to be more resistant and competitive. The total plant density of desirable species such as ryegrass was decreasing as weed infestation increases. Weeds intensity has high effect on the biomass production, which indicate that more of fertilize with water applied consumed by weeds. Furthermore, results clearly demonstrated the effect of weeds on biomass whereby weeds has high biomass at the high infestation. This suggests that some weeds are resistant to herbicide which makes them to remain competitive.

From these findings, nutritional analysis of these weeds would be necessary to examine the quality or condition of weeds in terms toxicity levels. Thus, also test out whether those weeds contribute on the total biomass does not have smell on the feed that could affect feed intake or quality of the milk. Furthermore, it is important that farmers do a good land preparation to minimize chances of the weeds to invade. This should be combined with the good grazing program so that the desirable species remain competitive against weeds at all time. Therefore, selection of species that are not susceptible to defoliation will help to suppress weeds through defoliation. In addition, choosing appropriate companionable species that will compete with weeds and manage nutrient availability at the appropriate rates will successful control wee infestation.

6. Acknowledgement

This paper adopted from Bachelor of Science in agriculture submitted in department of livestock and pasture at University of Fort Hare, South Africa .The authors grateful acknowledge the practical support from the community of University of Fort Hare and the staff of the livestock and pasture department.

References

Abaye*,* A.O., Scaglia, G., Teutsch, C., & Raines*,* P. (2009). The Nutritive Value of Common Pasture Weeds and Their Relation to Livestock Nutrient Requirements. College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University. Virginia Cooperative Extension. Publication 418-150.

Abdin , O.A ., Zhou , X.M., Cloutier , D., Coulman , D.C., Faris, M.A., & Smith, D.L.(2000). Cover crops and interrow tillage for weed control in short season maize (Zea mays). *European Journal of Agronomy*, 12, 93–102.

Al-Tawaha, A.R.M., Odat, N., Gzawi, A.L., Al-udatt, M.M., Turk, M., & Ababneh, F. (2008). Genomic and Chemical Approach to Weed Control in Pasture. American-Eurasian *Journal of Agriculture and Environmental Science*, 3(2), 1873-193.

Armin, M., & Asghripour, M. (2011). Effect of Plant Density on Wild Oat Competition with Competitive and Non- Competitive Wheat Cultivars. *Agricultural Sciences in China,* 10(10), 1554-1561.

Bridges, D.C. (1994). Impact of Weeds on Human Endeavors. *Weed Technology*, 8,392-395.

Celebi1, S.Z., Kaya, L., Sahar, A.K., & Yergin, R. (2010). Effects of the weed density on grass yield of Alfalfa (*Medicago sativa* L.) in different row spacing applications. *African Journal of Biotechnology*, 41(9), 6867-6872.

Chou, C., Hwang, S., & Peng, C. (1987). The selective allelopathic interaction of a pasture-forest intercropping in Taiwan. *Plant and soil*, 98, 31-41.

Colbach, N., & Sache, I. (2001). Blackgrass (*Alopecurus myosuroides* Huds.) seed dispersal from a single plant and its consequences on weed infestation. *Ecological Modelling*, 139,201–219.

Crouzet, O., Batisson, I., Besse-Hoggan, P., Bonnemoy , F., Bardot , C., Poly, F., Bohatier , J., & Mallet , C. (2010). Response of soil microbial communities to the herbicide mesotrione: A dose-effect microcosm approach. *Soil Biology & Biochemistry,* 42, 193-202.

De Bruijn, S.L., Bork, E.W., & Grekul, C.W. (2010). Neighbor defoliation regulates Canada thistle (Cirsium arvense) in pasture by mediating interspecific competition. *Crop Protection,* 29, 1489-1495.

Den Hollander, N.G., Bastiaans, L., & Kropff, M.J. (2007). Clover as a cover crop for weed suppression in an intercropping design II. Competitive ability of several clover species. *European Journal of Agronomy*, 26,104–112.

Edwards, C.A. (1989). Impact of herbicides on soil ecosystems. *Critical Reviews in Plant Sciences,* 8 (3), 221–257.

Fuhlendorf, S.D., Engle, D.A., O'Meilia, C.M., Weir, J.R., & Cummings, D.C. (2009). Does herbicide weed control increase livestock production on non-equilibrium rangeland? *Agriculture, Ecosystems and Environment*, 132, 1–6.

Gerlach, J. D., Dyer, A., & Rice, K. J. (1998). Grassland and foothill woodland ecosystems of the Central Valley. *Fremontia* 26, 39–43.

Goh, K.M., & Bruce, G.E. (2005). Comparison of biomass production and biological nitrogen fixation of multi-species pastures (mixed herb leys) with perennial ryegrass-white clover pasture with and without irrigation in Canterbury, New Zealand. *Agriculture, Ecosystems and Environment*, 110,230–240.

Harker, K. N., Baron, V. S., Chanasyk, D.S., Naeth, M. A, & Stevenson, F. C. (2000). Grazing intensity effects on weed populations in annual and perennial pasture systems. *Weed Science*, 48(2), 231-238.

Jones, G. G., Gée, Ch., &Truchetet, F. (2009). Modelling agronomic images for weed detection and comparison of crop/weed discrimination algorithm performance. *Precision Agriculture,* 10, 1-5.

Jones, R. E., & Medd, R. W. (2000). Economic thresholds and the case for longer term approaches to population management of weeds. *Weed Technology,* 14,337–50.

Matarczyk, J.A., Willis, A.J., Vranjic, A.J., & Ash, J.E. (2002). Herbicides, weeds and endangered species: management of bitou bush (Chrysanthemoides monilifera ssp. rotundata) with glyphosate and impacts on the endangered shrub, Pimelea spicata. *Biological Conservation*, 108, 133–141.

Mkhabela, T., & Mndeme, S.H. (2010).The cost of producing milk in the KwaZulu-Natal Midlands of South Africa: a cost-curve approach. *Agrekon: Agricultural Economics Research, Policy and Practice in Southern Africa*, 49, 122-142.

Mucina, L., & Rutherford, M.C. (eds) (2006). The vegetation of South Africa, Lesotho and Swaziland. *Sterlitzia* 19. South African National Biodiversity Institute, Pretoria.

Mueller-Warrant, G.W., Rosato, S.C., (2002). Weed Control for Stand Duration Perennial Ryegrass Seed Production: I. Residue Removed. *Agronomy Journal*, 94, 1181–1191.

Muller-Scharer, H. (1996). Interplanting ryegrass in winter leek: effect on weed control, crop yield and allocation of N-fertiliser. *Crop Protection*, 15, 641-648.

Nordblom, T.L., Pannell, D.J., Christiansen, S., Nersoyan, N., & and Bahhadya, F. (1994). From weed to wealth**?** Prospects for medic pastures in the Mediterranean farming system of north-west Syria. *Journal of Agricultural Economics*, 11(1), 29-42.

Olson, B.E., & Lacey, J.R. (1994). Sheep: A method for controlling Rangeland weeds. *Journal of sheep Research*, 105-112.

Puricelli, E., & Tuesca, D. (2005). Weed density and diversity under glyphosate-resistant crop sequences. *Crop Protection*, 24:533–542.

Randall, J. M. (1996). Weed control for the preservation of biological diversity. *Weed Technology,* 10, 370–83.

Robert, J., Kremer, H., & Jianmei, L.I. (2003). Developing weed-suppressive soils through improved soil quality management. Plant Science Unit, University of Missouri, Columbia, MO 65211, USA

Ross, S.M., King, J.R., Izaurralde, R.C., & O'Donovan, J.T. (2001). Weed Suppression by Seven Clover Species. *Agronomic Journal*, 93,820–827.

Singh, K., Agrawal, K.N., & Bora, G.C. (2011). Advanced techniques for Weed and crop identification for site specific Weed management. *Biosystems engineering*, 109, 52-64.

Strandberg, B., Pedersen, M.B., & Elmegaard, N. (2005). Weed and arthropod populations in conventional and genetically modified herbicide tolerant fodder beet fields. *Agriculture, Ecosystems and Environment*, 105, 243–253.

Tainton, N.M. (ed). (2000). Pasture management in South Africa. Pietermaritzburg: University of Natal Press.

Thorn, E. R. (1988). Changing seasonal growth of paspalum pastures by over drilling ryegrass and white clover. *Proceedings of the New Zealand Grassland Association*, 49,135- 140.

Tracy, B.F., &Sanderson, M. A. (2004). Forage productivity, species evenness and weed invasion in pasture communities. *Agriculture, Ecosystems and Environment,* 102,175–183.

Vila, M., Williamson, M., & Lonsdale, M. (2004). Competition experiments on alien weeds with crops: lessons for measuring plant invasion impact? *Biological Invasions*, 6**,** 59–69.

Yu, Y.W., Nan, Z.B. & Matthew, C. (2008). Population relationships of perennial ryegrass and white clover mixtures under differing grazing intensities. *Agriculture, Ecosystems and Environment*, 124, 40–50.