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Full Length Article

Biomass Accumulation and Weed Suppression by Winter Cereal Cover Crops in Maize-based Cropping Systems in the Eastern Cape, South Africa

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Abstract

White oats (*Avena sativa* variety Sederberg*)*, triticale (*Triticale secale* variety Korog), italian rye grass (*Lolium multiflorum* variety Energa) and barley (*Hordeum vulgare* variety SVG 13*)* were evaluated for biomass yield and weed suppression. A follow up maize trial was conducted to test the residual effect of cover crops. Triticale achieved the highest biomass yield of 13910 kg ha^{-1} and Italian ryegrass the lowest of 6452 kg ha^{-1}. Cover crop treatments consistently had lower weed dry weight ($p<0.01$) during cover crop phase and in subsequent maize compared to the weedy fallow. Italian ryegrass had the lowest weed dry weight but was similar to white oat and triticale in control of weeds. There were no significant differences in total soil nitrogen and phosphorus amongst the cover crop treatments and with the weedy fallow but significant difference ($p<0.05$) in maize yield was observed between the cover crop treatments and the weedy fallow. White oats produced the highest maize grain yield (6369 kg ha^{-1}), which was 33% more than the weedy fallow plot having the least maize grain yield of 4784 kg ha^{-1}. It was concluded that it may be feasible to increase cover crop biomass yield in conservation agriculture systems in the Eastern Cape through the selection of white oat and triticale as cover crops.

Keywords: Conservation agriculture; Italian ryegrass; Triticale; White oats

Introduction

Land degradation is a major challenge to sustainable crop production on many small-scale farms in the Eastern Cape (EC) province of South Africa. Burning of crop residues and continuous tillage with the plough has led to excessive soil erosion (Laker, 2004). Increasing interest in conservation agriculture (CA) in South Africa has been due to the practice substantially reducing erosion if properly implemented. However, lack of adequate soil cover has been a negative factor adversely affecting the practice of CA in a number of agricultural development projects attempted to promote the practices amongst small-scale farmers in the EC and other parts of South Africa (Derpsch, 2003). The three pillars of CA are, (i) minimal soil disturbance, through zero tillage and direct drilling, (ii) ecologically viable crop rotations and, (iii) permanent soil cover provided by cover crops.

All three principles are important for practicing CA. The need to identify high biomass yielding cover crops was suggested as a solution to lack of cover in small-scale CA farmers' fields in South Africa by Derpsch (2003) based on the Brazilian experiences. High biomass of live and dead mulches of cover crops results in erosion control and moisture conservation.results in erosion control and moisture conservation. It is known to reduce light transmittance to the soil surface hence reducing weed seed germination (Teasdale and Daughtry, 1993). Low and poorly distributed seasonal rainfall and high weed pressure are bio-physical constraints faced by small-scale farmers in South Africa at marginal lands (Derpsch, 2003; Van Averbeke and Bennett, 2007). An ideal cover crop suited to their cropping systems would provide adequate biomass levels with minimal rainfall and soil fertility, suppress weeds both in the cover crop and subsequent crop and conserve soil moisture. Cereal cover crops compared to legumes have high carbon: nitrogen (C/N) ratio and the higher C/N ratio, lignin and polyphenol contents of the cereal cover crop is important in terms of soil erosion and weed control as the residues persist for a longer time maintaining cover over the soil surface (Sakala *et al*., 2000). Pervaiz *et al*. (2009) showed that mulching with straw improved soil physical health and maize crop quality in studies carried out in Faisalabad, Pakistan.

A number of cereal species have been tested as cover crops and have some of the attributes that make them

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appropriate for the small-scale cropping systems in South Africa. For instance, barley (*Hordeum vulgare*), have high tillering ability with an added advantage of drought tolerance (Raderschall and Gebhardt, 1990) and capable of producing high biomass yield. Triticale (*Triticale secale*), on the other hand is hardier, tolerate cold temperatures, making it a good option when planting is delayed. Italian ryegrass (*Lolium multiflorum*) is deep rooted, allow exploitation of nutrients and moisture from deeper soil horizons (Fourie *et al*., 2001). These species offer the opportunity to widen the range of cover crops in CA systems in the small-scale farming sector of South Africa.

Farmers' cropping systems and management of staple crop have also to be taken into consideration when integrating cover crops. Farmers in small scale irrigation schemes in the EC are known to plant maize late in summer (Fanadzo *et al*., 2009) making early establishment of winter cover crops difficult. This can compromise cover crop biomass accumulation due to low temperatures during early growth. Cover crops such as triticale being winter hardy, could be critical for maximization of biomass. Conservation tillage was suggested as a possible solution to late planting of wheat in rice-wheat systems in Pakistan and the practice contributed to stable yield of wheat (Mann *et al*., 2008). Planting of wheat was delayed by number of reasons including excessive tillage, soil moisture problems and consequently prolonged land preparation. Adoption of zero-till, an important principle of CA has been demonstrated to improve the sustainability of wheat production in irrigated areas of the Punjab, Pakistan (Mann *et al*., 2008).

Biomass production by the cover crops is of paramount importance for successful weed suppression, but other mechanisms of weed control also play a role in weed control. Winter cereal cover crops such as barley (*H. vulgare*), Italian ryegrass (*L. multiflorum*), perennial ryegrass, wheat (*Triticum aestivum*), rye and oats (*Avena sativa*) are also known to be allellopathic, suppressing weed germination and establishment by releasing allellochemicals such as phenolic acids (Weston, 1996). Rehman *et al*. (2010) showed that herbicide dosage could be reduced by 20-67% when used in combination with mixture of allelopathic water extracts of sorghum, sunflower and rice in rice. This phenomenon could also be exploited for integrated weed control in small-scale maize-based cropping systems in the EC. Fourie *et al*. (2001) found that cover crops could also suppress weeds due to their growth habit like Italian ryegrass, with a creeping and tufted growth habit.

Cultural weed control method is an important option for resource poor small-scale farmers of the EC using manual weed control methods. These farmers sometimes resort to the abandoning of crop fields when they fail to control weeds (Fanadzo, 2007), with high financial losses and exposing farming households to food insecurity. Small-scale farmers could be motivated to adopt cover crops if there is effective demonstration of weed control, reduction in the requirement of herbicides and reduced labor costs for manual weed control.

Although winter cereal cover crops do not fix nitrogen and use residual nitrogen that may otherwise be leached (McCracken *et al.*, 1994). This can help in nutrient cycling, making the inorganic nitrogen available to the subsequent crop. However, Schomberg *et al.* (2005) found that the amount of nitrogen fixed or retained by cover crops is not always related to the biomass produced. In their study, even though rye produced 40 to 60% more biomass than black oats, crimson clover and oilseed radish it had the least amount of nitrogen. Problems of nutrient immobilization can also occur which can be detrimental to the follow up crop in terms of nutrient availability.

The overall benefit of cover crops will be realized in increased yield of a follow-on main crop. Higher yields have been attributed to improvement in soil quality (Govaerts *et al*., 2006; Hayat and Ali, 2010) and reduction of weeds (Mann *et al*., 2008). Kramberger *et al*. (2009) found similar yields of maize after different cover crops (winter rape, sub clover and crimson clover) and weedy fallow whilst a negative effect was observed with Italian ryegrass which reduced maize yield from 9.3 t ha^{-1} to 7.7 t ha^{-1}. This can probably be attributed to the Italian ryegrass locking up nutrients and slowing nutrient release.

The quality of cover crop species in terms of chemical composition should be a critical factor when selecting cover crops either for improving soil nutrient status or for weed suppression, moisture conservation and control of erosion. The objectives of this study were therefore to evaluate winter cereal cover crop species for biomass production, weed suppression and their residual effects on subsequent maize yield, weeds and soil N, P and organic carbon.

Materials and Methods

Location and Site Characteristics

The research was conducted at the University of Fort Hare Research Farm, South Africa (32°46' S, 26°50' E) during the 2008 winter and 2008-2009 summer seasons. The farm's mean altitude is 535 m above sea level (m.a.s.l) with mean annual rainfall of 575 mm, received mainly in the summer months of November to March. The mean temperature was 17.8°C, ranging from 11.1°C in winter to 24.6°C in summer. The soil is classified as Luvisol in the FAO system with 64.2% sand, 16.0% silt and 19.8% clay. The soil had a pH of 6.1 (2.5:1 water to soil), 0.35 g P kg^{-1}, 4.04 g K kg^{-1} and 4.25 g Ca kg^{-1} (Mandiringana *et al*., 2005).

Experimental Design and Management

Four winter cereal cover crop species were evaluated for biomass accumulation and weed suppression. The cover crop species were white oats (*A. sativa* variety Sederberg), triticale (*T. secale* variety Korog), Italian ryegrass (*L. multiflorum* variety Energa) and barley (*H. vulgare* variety

SVG 13*)*. The treatments were laid in a randomized complete block design with three replications. A control plot was included with no cover crop grown. The gross plot size was 5.4 m × 5 m and net plot of 4.5 m × 3 m.

The cover crops were planted in furrows opened up using hand hoes. The cover crop experiment was planted on 30th May 2008 in the winter season. The different cover crop species seed rates used were 100 kg ha^{-1} for white oats, triticale and barley and 40 kg ha^{-1} for Italian ryegrass (Fourie *et al*., 2001). The cover crops were drilled in furrows 20 cm apart. Basal fertilizer application was 200 kg ha^{-1} of compound 2:3:4 (30+ 0.05% Zn) at planting. Top dressing of 150 kg ha^{-1} of Lime Ammonium Nitrate (LAN) (28% of N) was applied 6 weeks after planting to supply 42 kg N ha^{-1}. No weed control was done to the winter cover crops due to low weed infestation. The cover crops were terminated using a tractor drawn roller at early reproductive stage and by applying Erase 360 SL [Glyphosate (Isopropyl amine salt)] using 3 L ha^{-1} before their degradation on the soil surface.

A subsequent maize crop was established in 2008-2009 summer season. The maize was no-till planted into the winter cereal experiment plots on 17 December 2008 at spacing of 0.9 m × 0.27 m to achieve a plant population of about 40 000 plants ha^{-1}. The gross maize plots were seven rows per plot each 5 m long. The maize net plot was three middle rows each 3 m long. Variety SC701, a popular hybrid variety with local farmers was used. Fertilizer application to the maize crop was 60 kg N ha^{-1} with the nitrogen applied as basal [Compound 2:3:4 (30+ 0.05% Zn)] at planting. The remainder was applied as top dressing (LAN (28% of N) at 6 weeks after planting. Weed control was done once at 2 weeks after planting, by hand hoeing. Prophylactic sprays of Bulldock 25EC (Beta-cyfluthrin 50 g L^{-1}) were done at 6 weeks after planting against maize stalk borer (*Buseolla fusca*) attack. Water was supplied using the sprinkler irrigation system based on evaporation pan readings.

Measurements

Soil samples were taken before planting cover crops and maize to a depth of 0-15 cm, air dried and sieved (<2 mm sieve) before analysis of total N, extractable P, organic C, pH and exchangeable bases (Ca, K, Na and Mg) (Okalebo *et al*., 2002). Two quadrats measuring 0.35 m × 0.35 m were randomly placed in plots of each cover crop at 53, 78, 106 and 124 days after planting (DAP) for destructive measurement of cover crop and weed dry matter accumulation after oven drying at 65°C to a constant weight. In the follow maize crop, two quadrats measuring 0.35 m × 0.35 m were randomly placed into plots previously grown to cover crops to measure weed biomass and species at 33 and 68 DAP after oven drying at 65°C to a constant weight. At maize harvest, cob weight and grain yield were measured and maize grain yield adjusted to 12.5% moisture content.

Data Analysis

Cover crop and weed biomass, weed species counts and maize yield were subjected to analysis of variance using the Genstat Release 7.22 DE package. Data on weed species count was transformed using the square root transformation. Significant differences were identified at p=0.05. Treatment means were separated using least significance procedure (LSD). A regression analysis was conducted to test the relationships of cover crop dry weight, weed dry weight and maize grain yield. Cover crop growth rate was analyzed by comparing the slopes of the regression lines when cover crop dry weight accumulation was plotted against time (Gomez and Gomez, 1984). The slopes shown by the regression coefficients give an indication of the crop growth rate (Fageria *et al*., 2006).

Results

Cover Crop Biomass Accumulation

There was a significant difference (p<0.01) in biomass amongst cover crop species at 124 DAP. Triticale achieved the highest biomass of 13910 kg ha^{-1} significantly higher (p<0.01) than white oat and barley yielding the same biomass (Table 1). Italian ryegrass was significantly lower (p<0.01) than all other species tested in the experiment and achieved biomass yield of 6452 kg ha^{-1}. There were significant differences (p<0.001) in cover crop growth rates. The trend in crop growth rate was similar to observations made on biomass yield. Triticale had the highest crop growth rate followed by barley and white oats and Italian ryegrass (Table 1).

Weeds Dry Weights and Weeds Species in the Cover Crops

There was significant difference (p<0.001) in weed dry weight amongst the cover crop species at 53, 78, 106 and 124 DAP (Table 2). All cover crop treatments consistently had lower weeds dry weights compared to the weedy fallow treatment at all sampling dates. The cover crop treatments differed in weeds dry weight at all the sampling dates and Italian ryegrass achieved the lowest weeds dry weight at all sampling dates up to cover crop termination at 124 DAP. White oat and triticale performed at similar to Italian ryegrass except at 53 DAP when Italian ryegrass had significantly lower (p<0.05) weeds dry weight (Table 2). Barley consistently had higher weed dry weight at all sampling dates compared to other cover crop treatments.

There was no significant difference (p>0.05) in weed species counts amongst the cover crop treatments and with the weedy fallow at 58 and 106 DAP. Significant differences (p<0.01) in weed species count was observed at 78 and 124 DAP. Italian ryegrass had significantly lower (p<0.01) weed species count than all other treatments at 78 DAP.

Table 1: Cover crop biomass accumulation and growth rates in the 2008 winter season

	Biomass (kg ha^{-1})	Slope	R^2
Oats	10437.00 b	123.69 b	0.98
Italian Ryegrass	6452.00 c	57.50 c	0.97
Barley	10802.00 b	126.98 b	0.94
Triticale	13 910.00 a	166.24 a	0.96
Significance	**	***	
$LSD_{(0.05)}$	2500.10	33.29	
CV (%)	12.00	14.00	

Means followed by different letters differ significantly at p=0.05. $LSD_{(0.05)}$ represents least significant difference at 5% level. CV represents coefficient of variation. *, ** and *** represents significance at p=0.05, p = 0.01 and p = 0.001 respectively

Table 2: Effect of winter cover crop treatments on weeds dry weight at different sampling dates during the cover crop phase in the 2008 winter season

	Weeds dry weight (kg ha^{-1})			
	53 DAP	78 DAP	106 DAP	124 DAP
White oats	253.00 d	182.00 c	208.00 dc	203.00 c
Italian ryegrass	79.00 e	31.00 c	94.00 d	47.00 c
Barley	480.00 b	849.00 b	984.00 b	642.00 b
Triticale	379.00 c	212.00 c	277.00 c	155.00 c
Weedy fallow	794.00 a	2998.00 a	3810.00 a	6965.00 a
Significance	***	***	***	***
$LSD_{(0.05)}$	72.70	247.60	143.30	396.10
CV (%)	9.70	15.40	7.10	13.10

DAP represents days after planting. Means followed by different letters differ significantly at p=0.05. LSD $_{(0.05)}$ represents least significant difference at 5% level. CV represents coefficient of variation. *, ** and *** represents significance at p=0.05, p = 0.01 and p = 0.001 respectively

Table 3: Effect of winter cereal cover crop treatments on weeds species count at different sampling dates (DAP) in the 2008 winter growing season

	Weeds Species			
	53 DAP	78 DAP	106 DAP	124 DAP
White oats	2.57	2.51 a	2.23	2.08 b
Italian ryegrass	2.44	1.91 b	1.99	1.73 c
Barley	2.45	2.64 a	2.23	2.32 a
Triticale	2.38	2.64 a	2.15	2.45 a
Weedy fallow	2.44	2.58 a	2.45	2.38 a
Significance	NS	**	NS	***
$LSD_{(0.05)}$	-	0.37	-	0.20
CV (%)	6.70	8.00	10.50	4.90

DAP represents days after planting. Means followed by different letters differ significantly at p=0.05. LSD $_{(0.05)}$ represents least significant difference at 5% level. CV represents coefficient of variation. *, ** and *** represents significance at p=0.05, p = 0.01 and p = 0.001 respectively

All other cover crop species did not differ with the weedy fallow with respect to species number at this sampling date. At 124 DAP Italian ryegrass had the least number of weed species. However, at this sampling date, though white oat had more weed species than Italian ryegrass, the number of weed species was significantly lower in barley and triticale, both of which did not differ to the weedy fallow (Table 3). Major weed species observed in the winter were *Galinsoga parviflora, Lamium amplexicaule, Conyza canadensis, Lactuca serriola, Senecio vulgaris and Crepis runcinata*.

Total Carbon and N and Extractable P

There was no significant difference (p>0.05) in total soil nitrogen and phosphorus amongst the cover crop treatments and with the weed fallow (Table 4). However, Italian ryegrass had significantly higher (p<0.01) organic carbon than other cover crop treatments and the weedy fallow.

Weeds in Maize

There were significant differences (p<0.01) in weed dry weight amongst the treatments at 33 and 68 DAP in the subsequent maize crop. White oat, Italian ryegrass and triticale all had lower weed dry weights compared to the weedy fallow at both sampling dates. Barley did not differ to the weedy fallow with respect to weed dry weight at both sampling dates (Table 5). The summer weeds found were *Galinsorga parviflora, Amaranthus hybridus, Chenopodium album, Portulaca oleracea, Cyperus esculentus and Nicandra physaloides*.

Maize Grain Yield

There was a significant difference (p<0.05) in maize yield observed between cover crop treatments and weedy fallow. However, no difference in maize yield amongst the cover crop treatments was found. Inclusion of cover crops increased maize grain yield by 21-33% compared to the weedy fallow (Table 6).

There was a significant (p<0.05) relationship of maize grain yield and early weed dry weight at 33 DAP (Fig. 1) and late weed dry weight 68 DAP (Fig. 2) in the maize crop. As the weed dry weight increased the maize grain yield decreased, however, no significant relationship (p>0.05) between maize grain yield and cover crop dry weight, soil total nitrogen and soil total phosphorus and organic carbon.

Discussion

All cover crops produced biomass levels above the 6 t ha^{-1}, the minimum expected for success of CA (Derpsch, 2003). The highest biomass accumulated by Italian ryegrass, compared to all the other cover crops could be attributed to its fast growth at early stages. Fourie *et al*. (2001) reported that the root system of Italian rye grass grows fast, become extensive and as deep as one meter early in the growing season. This allowed Italian rye grass to have better competitive advantage for resources over weeds than other cover crop species. The higher temperature experienced at the beginning of the growing season (data not shown) could also have favored the accumulation of more biomass by the Italian ryegrass when compared with other species. Triticale, for instance, is reported to be sensitive to warmer temperatures and resulted in low biomass recorded during early stages of growth being winter hardy and grows well under cooler conditions (Fourie *et al*., 2001).

Table 4: Residual effect of the winter cereal cover crop species on soil total nitrogen, organic carbon and phosphorus

	Selected soil properties		
	Total N	OC	P
	%	%	mg kg^{-1}
White oats	0.34	0.31 b	2.68
Italian ryegrass	0.30	0.51 a	2.75
Barley	0.31	0.40 b	2.87
Triticale	0.28	0.29 b	2.42
Weedy fallow	0.29	0.34 b	2.44
Significance	NS	**	NS
LSD $_{(0.05)}$	0.07	0.11	0.74
CV (%)	12.00	15.70	15.00

Means followed by different letters differ significantly at p=0.05. LSD $_{(0.05)}$ represents least significant difference at 5% level. CV represents coefficient of variation. *, ** and *** represents significance at p=0.05, p = 0.01 and p = 0.001 respectively

Table 5: Effect of winter cereal cover crop species on weeds dry weight in the subsequent summer maize crop

	Weeds dry weight (kg ha^{-1})	
	33 DAP	68 DAP
White oats	1207 c	784 c
Italian ryegrass	1510 bc	1003 bc
Barley	1745 ab	1134 ab
Triticale	1209 c	786 c
Weedy fallow	2150 a	1398 a
Significance	**	**
LSD$_{(0.05)}$	440.40	291.40
CV (%)	15.00	15.20

Means followed by different letters differ significantly at p=0.05. LSD $_{(0.05)}$ represents least significant difference at 5% level. CV represents coefficient of variation. *, ** and *** represents significance at p=0.05, p = 0.01 and p = 0.001 respectively

Table 6: Residual effect of winter cereal cover crop species on maize grain yield

	Maize grain yield (kg ha^{-1})	Yield increase (%)
White oats	6369 a	33.00
Italian ryegrass	5809 a	21.00
Barley	5974 a	25.00
Triticale	6047 a	26.00
Weedy fallow	4784 b	-
Significance	*	
LSD$_{(0.05)}$	932.50	
CV (%)	8.50	

Means followed by different letters differ significantly at p=0.05. LSD $_{(0.05)}$ represents least significant difference at 5% level. CV represents coefficient of variation. *, ** and *** represents significance at p=0.05, p = 0.01 and p = 0.001 respectively

Andraski and Bundy (2005) attributed low biomass production by triticale at early stages of growth to its use of energy to store carbohydrates in the root system for survival during the winter season.

The lack of significant difference in weed species count amongst the different treatments at 53 DAP may be attributed to slow growth of cover crops at the time of sampling. This was probably due to low cover crop biomass which could not impose significant effects on the weed seed germination and growth. Significant difference was noticed at later stages as cover crops accumulated more biomass. Less weed species and weed dry weights were observed in the Italian ryegrass plots despite having low biomass (Table 1 and 3). Italian ryegrass might have used its spreading and tufted growth habit to effectively smoother weeds. Fourie *et al*. (2001) reported this phenomenon in *Phalaris* and *Lolium* species. Triticale and barley on the other hand are erect and might allow the germination and growth of weeds. This demonstrates well the effect of plant architecture as well as growth habit as critical for weed suppression. A rather inconsistent result was observed at 106 DAP, where significant differences were not observed in weed species counts (Table 3). This could be a probable indication of robustness of weed species composition due to changes in cropping systems as reported by Ngouajio and Mennan (2005).

However, high cover crop biomass accumulation remains critical in suppressing weeds as demonstrated well by the three erect cover crops triticale, oats and barley which imposed a significant effect on the weed dry matter. This was also reported by Ngouajio and Mennan (2005) in which correlation of weed suppression and cover crop biomass accumulation was found. However, we cannot wholly attribute weed suppression to cover crop dry matter accumulation only as there might be possibility of other factors such as allelopathy. All the cover crop species tested are known to be allellopathic, suppressing weed germination and establishment by releasing allellochemicals (Weston, 1996).

The difference in maize grain yield in the cover crop plots in comparison to weedy fallow demonstrated the importance of winter cover crops. The high biomass accumulated by triticale and white oats could have resulted in high maize grain yields obtained in the plots. Biomass of cover crops is known to affect subsequent crops by increase in nutrients, soil properties, moisture conservation and weed suppression (Teasdale and Mohler, 2000; Crandall *et al*., 2005). Winter cover crops could have had an effect on soil moisture, soil nutrition and weeds in the subsequent season. There was however, no significant relationship of winter cover crop biomass production and maize grain yield. Cover crops like Italian ryegrass produced low biomass and had significant effects on weeds and soil properties than the other cover crops producing higher biomass.

There was no significant relationship of soil total nitrogen, total phosphate and organic carbon at maize planting and subsequent maize grain yield. Other researchers obtained a significant increase in soil nutrients after cover crops. Cereal cover crops cannot biologically fix nitrogen, but can capture nitrogen from the soil profile and minimize leaching (McCracken *et al.*, 1994; Schomberg *et al*., 2005). The lack of nutrient benefits to the subsequent maize, in this study, could be due to prolonged length of period between cover crop termination and soil sampling. Leaching of nutrients could have occurred due to early

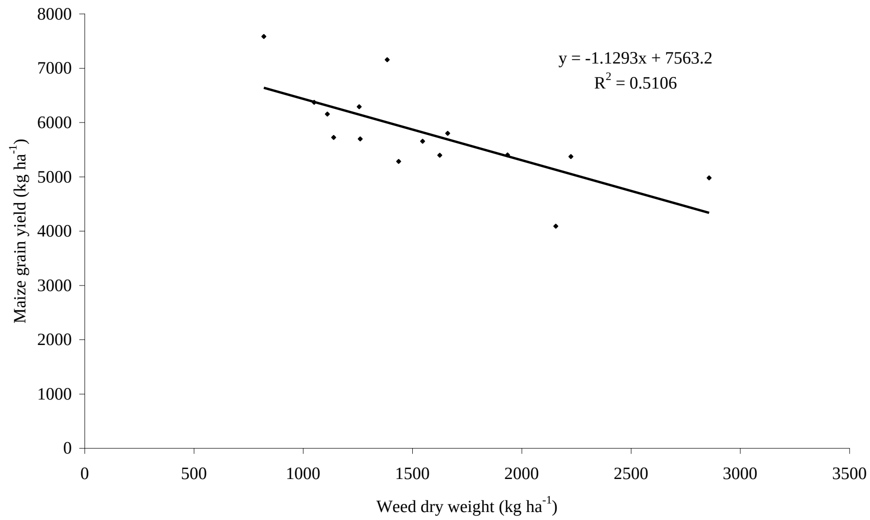

Fig. 1: Relationship of maize grain yield and early weed dry weight

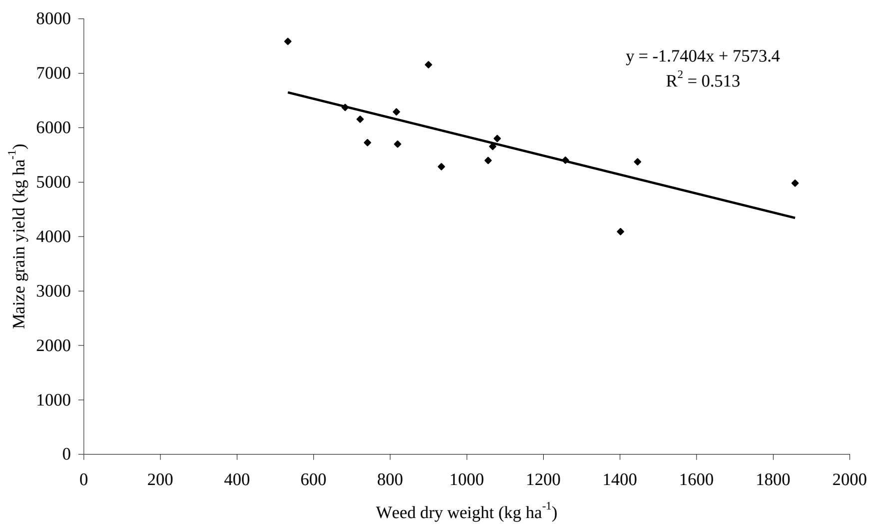

Fig. 2: Relationship of maize grain yield and late weed dry weight

summer rains before maize establishment and 95.4 mm of rainfall received during the fallow period between September and December 2008.

A significant relationship was observed between maize grain yield and winter and summer weed dry weight. Differences in weed dry weight observed in maize previously under the cover crop species could be attributed to the different cover crop species. The high weed dry weight in the weedy fallow plot highlighted the importance of cover in weed suppression. White oats and triticale had the lowest weed dry weight due to high biomass from the cover crop species. Various cover crop species suppressed growing weeds as well as germinating weed seeds by modifying the conditions under which weeds germinate either by changing soil temperature, increase in soil moisture and physical impediment of weed seedlings (Teasdale and Mohler, 2000). White oats and triticale are also known to produce allellopathic chemicals (Weston, 1996), which might have played a role in suppression of weeds. However, in this study the effect of allelopathy from the different cover crops on weed suppression was not observed. Another factor which was not observed in the present study was soil moisture conservation by the cover crop residues.

Conclusion

Triticale, barley and oats produced high levels of biomass and should be considered as cover crops in maize-based cropping systems of the EC. Oats, Italian ryegrass and triticale were equally effective in suppressing weeds at cover crop termination and in the subsequent maize phase. It can be concluded that all three latter cover crop species are suited for winter cover cropping in the EC. The fact that yield trends of the subsequent maize crop seemed to favor oats and triticale would suggest these two as the priority species to be targeted for promotion in the maize-based cropping systems of the EC.

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References

Andraski, T.W. and L.G. Bundy, 2005. Cover crop effects on corn yield response to nitrogen on an irrigated sandy soil. *Agron. J.,* 97: 1239−1244

Crandall, S., M. Ruffo and G.A. Bollero, 2005. Cropping system and nitrogen dynamics under a cereal winter cover crop preceding corn. *Plant Soil*, 268: 200−219

Derpsch, R., 2003. *South Africa Report, Promotion of Conservation Agriculture.* Project Number TCP/SAF/2902. National Department of Agriculture Final Report, Pretoria, South Africa

Fageria, N.K., V.C. Baligar and R.B. Clark, 2006. *Physiology of Crop Production*, 1st edition. Harworth Press, New York, USA

Fanadzo, M., 2007. Weed management by small-scale irrigation farmers-the story of Zanyokwe. *S.A. Irrig.*, 29: 20−24

Fanadzo, M., C. Chiduza and P.N.S. Mnkeni, 2009. Investigation of agronomic factors constraining productivity of grain maize (*Zea mays* L.) at Zanyokwe irrigation scheme, Eastern Cape, South Africa. *J. Appl. Biosci.*, 17: 948−958

Fourie, J.C., P.J.E. Lauw and G.A. Agenbag, 2001. Effect of seeding date on the performance of grasses and broadleaf species evaluated for cover crop management in two wine grape regions of South Africa. *S Afr. J. Plant Soil*, 18: 118−127

Gomez, K.A. and A.A. Gomez, 1984. *Statistical Procedures for Agricultural Research*, 2nd edition. Wiley-Interscope, Singapore

Govaerts, B., M. Mezzalama, K.D. Sayre, J. Crossa, J.M. Nicol and J. Deckers, 2006. Long term consequences of tillage, residue managements and crop rotation on maize/wheat root rot and nematode population. *Appl. Soil Ecol.*, 32: 305−315

Hayat, R. and S. Ali, 2010. Contribution of water use efficiency of summer legumes for the production of rainfed wheat. *Int. J. Agric. Biol*., 12: 655−660

Kramberger, B., A. Gselman, M. Janzekovic, M. Kaligaric and B. Bracko, 2009. Effect of cover crop species on soil mineral nitrogen and on yield and N content of maize. *Eur. J. Agron.*, 31: 103−109

Laker, M.C., 2004. Advances in soil erosion, soil conservation, land suitability evaluation and land use planning research in South Africa, 1978−2003. *S Afr. Plant Soil*, 21: 345−368

Mandiringana, O.T., P.N.S. Mnkeni, Z. Mkile, W. van Averbeke, E. van Ranst and H. Varplancke, 2005. Mineralogy and fertility status of selected soils of the Eastern Cape Province, South Africa. *Commun. Soil Sci. Plant Anal.*, 36: 2431−2446

Mann, R.A., M. Ramzan and A. Munir, 2008. Improving the sustainability of wheat production in irrigated areas of Punjab, Pakistan through conservation tillage technology. *Int. J. Agric. Biol*., 10: 249−254

McCracken, D.V., M.S. Smith, J.H. Grove, C.T. MacKown and R.L. Blevins, 1994. Nitrate leaching as influenced by cover cropping and nitrogen source. *Soil Sci. Soc. Amer. J*., 58: 1476−1483

Ngouajio, M. and H. Mennan, 2005. Weed populations and prickling cucumber (*Cucumis sativus*) yield under summer and winter cover crop systems. *Crop Prot.*, 24: 521−526

Okalebo, J.R., K.W. Gathua and P.L. Woomer, 2002. *Laboratory Methods for Soil and Plant Analysis: A Working Manual*. TSBF Program UNESCO ROSTA Soil Science Society of East Africa A Technical Publication No.1, Marvel EPZ Ltd, Nairobi, Kenya

Pervaiz, M.A., M. Iqbal, K. Shahzad and A.U. Hassan, 2009. Effect of mulch on soil physical properties and N, P, K concentration in maize (*Zea mays* L.) shoots under two tillage systems. *Int. J. Agric. Biol*., 11: 119−124

Raderschall, R. and H. Gebhardt, 1990. Field experiments on the Nmin-dynamics of an aquic plaggen soil cultivated with winter crops following legumes (*Vicia faba* L.). *J. Plant Nutr. Soil Sci*., 153: 75−80

Rehman, A., ZA. Cheema, A. Khaliq, M. Arshad and S. Mohsan, 2010. Application of sorghum, sunflower and rice water extract combinations helps in reducing herbicide dose for weed management in rice. *Int. J. Agric. Biol*., 12: 901−906

Sakala, W., G. Candisch and K.E. Giller, 2000. Interactions between residues of maize, pigeonpea and mineral N fertilizers during decomposition and N mineralization. *Soil Biol. Biochem*., 32: 679−683

Schomberg, H.H., D.M. Endale, A. Calegari, R. Peixoto, M. Miyazawa and M. Cabrera, 2005. Influence of cover crops on potential nitrogen availability to succeeding crops in a Southern Piedimont Soil. *Biol. Fert. Soils*, 42: 299−307

Teasdale, J.R. and C.L. Mohler, 2000. The quantitative relationship between weed emergence and the physical properties of mulches. *Weed Sci*., 48: 385−392

Teasdale, J.R. and C.S. Daughtry, 1993. Weed Suppression by live and desiccated hairy vetch (*Vicia villosa*). *Weed Sci*., 41: 207–212

Van Averbeke, W. and J. Bennett, 2007. Agroecology, Land Use and Smallholder Farming in Central Eastern Cape. *In*: *Livelihoods and landscapes, the People of Guquka and Koloni and their Resources*, pp: 67−90. Hebinck, P. and P.C. Lent (eds.). Koninklijke Brill NV, Leiden, The Netherlands

Weston, L.A., 1996. Utilization of allelopathy for weed management in agro ecosystems. *Agron. J.,* 88: 860−866

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