African Journal of Rural Development, Vol. 2 (3): July - September 2017: pp.441-453. ISSN 2415-2838

Composition and management of weed flora in smallholder farmers' fields in Swaziland

T. L. MNCUBE, [1] H. R. MLOZA-BANDA,[1] D. KIBIRIGE,[2] M. M. KHUMALO,[2] W. O. MUKABWE[3] and B. P. DLAMINI[2]

[1]Department of Crop Production, University of Swaziland, Private Bag 4, Kwaluseni, M201, Swaziland

[2]Department of Agricultural Economics and Agribusiness Management, University of Swaziland, Private Bag 4, Kwaluseni, M201, Swaziland

[3]Department of Agricultural and Bio-systems Engineering, University of Swaziland, P. O. Box Luyengo, Swaziland

Corresponding author: tenzytee@gmail.com

ABSTRACT

The weed flora in smallholder farmer's fields and the potential arable farmers have on their weeds in Swaziland were investigated in the 2015/2016 cropping season. The study was conducted in five agro-ecological zones, 117 fields and 99 farmers were interviewed. All together 34 weed species from 18 families were identified. Using the Shannon's index, the Highveld of Swaziland had the highest species diversity as compared to the other regions with the Lowveld having the lowest diversity. With Jaccard's index for comparing communities, the Highveld and Upper Middleveld had the highest number of species in common as compared to the Highveld and the Lowveld which had the least. *Commelina benghalensis* (L.) was the most abundant weed species in the Highveld and Upper Middleveld with *Acanthospermum hispidum* (DC) being the most abundant in the Lower Middleveld, *Richardia scabra* (L.) in the Lubombo and *Eleusine indica* (L.) Gaertn in the Lowveld, respectively. The second part of the study involved semi structured interviews where farmers were asked to identify and characterize weeds that are most problematic, aggressive and difficult to control. *Cynodon dactylon* (L.) Pers. was found to be the most problematic and difficult to control whilst *Richardia scabra* (L.) and *Xanthium strumarium* (L.) were the most aggressive weeds. From this study, it was noted that some weed species (*Corchorus olitorius* L., *Amaranthus hybridus* L. and *Bidens pilosa* L.) were among weeds that were left unweeded due to their contribution to the farmer's diet. It was also noted that 82% of the farmers practiced post-harvest weed management whilst 80% managed their headlands. Weed surveys remain integral to identifying possible problematic weeds and weed population shifts and directing research towards new or improved control measures.

Key words: Agro-ecological zone, diversity, relative abundance, weeds, Swaziland

RÉSUMÉ

La flore des adventices dans les champs des petits producteurs et le potentiel que les producteurs ont sur leurs adventices au Swaziland ont été étudiées lors de la campagne agricole 2015/2016. L'étude a été menée dans cinq zones agro-écologiques à travers 117 champs et 99 agriculteurs ont été interviewés. De façon globale, 34 espèces d'adventices de 18 familles différentes ont été identifiées. À l'aide de l'indice de Shannon, Highveld du Swaziland avait la plus grande diversité d'espèces par rapport aux autres régions, avec Lowveld ayant la plus faible diversité. La comparaison des communautés à partir de l'indice de Jaccard a montré que Highveld et Upper Middleveld avaient le plus grand nombre d'espèces en commun comparativement à Highveld et Lowveld qui en avaient le moins. *Commelina benghalensis* (L.) était l'espèce d'adventice la plus abondante dans Highveld et Upper Middleveld avec *Acanthospermum hispidum* (DC), *Richardia scabra* (L.), *Eleusine indica* (L.) Gaertn étant l'espèce la plus abondante respectivement dans le Bas Moyen-Age, Lubombo et Lowveld. La deuxième partie de l'étude portait sur les entretiens semi-structurées où les producteurs étaient invités à identifier et à caractériser les adventices qui sont les plus problématiques, agressives et difficiles à contrôler. *Cynodon dactylon* (L.) Pers. a été citée comme l'adventice la plus problématique et difficile à contrôler alors que Richardia scabra (L.) et *Xanthium strumarium* (L.) étaient les adventices les plus agressives. À partir de cette étude, il a été

Received: 13 May 2016
Accepted: 16 June 2017
Published: 30 September 2017

noté que certaines espèces d'adventices (Corchorus olitorius L., Amaranthus hybridus L. et Bidens pilosa L.) ne sont pas désherbées des champs en raison de leur contribution au régime alimentaire du producteur. Il a été également noté que 82% des producteurs pratiquent la gestion des adventices après la récolte, tandis que 80% nettoient le bord des champs. Les enquêtes sur les adventices restent essentielles pour identifier les éventuels adventices problématiques et les changements au niveau des populations d'adventices, et orienter la recherche vers des mesures de contrôle nouvelles ou améliorées.

Mots clés : Zone agro-écologique, diversité, abondance relative, adventices, Swaziland

INTRODUCTION

In Swaziland, approximately 80 per cent of farmers obtain their land preparation equipment, mostly tractors, from the tractor hire services administered by the Government of Swaziland through a scheme first introduced in 1997. However, primary tillage draft power has not been matched with concomitant technology for secondary operations such as that for weed removal. Farmers rarely use herbicides as a measure of weed control. Mostly they weed once using a hand hoe at varying times after crop emergence. Where herbicides are used, post-emergence formulations are preferred. Gianesi (2009) observed that common constraints accompanying herbicide use amongst smallholder farmers include inadequate knowledge of which herbicide to use in a given weed-crop situation as well as poor timing of application. It is therefore not inconceivable that current weed control practices in Swaziland remain grossly inadequate in bringing weeds under control with estimated losses in maize yield of up to 70% based on field appraisals (IRD, 2012).

Zimdahl (2007) observed that weed problems must be defined by species, and located in the field or area to be managed before solutions are proposed. In addition, it is considered that effort should be directed towards identifying those weeds considered problematic weeds like perennial parasitic weeds and hard to control annuals. The weed species composition and distribution of a given area are influenced by environmental and biological factors that determine the habitat type (Radosevich *et al.,* 1997). Invariably, human efforts to control weeds in a crop further influence weed communities (William *et al.,* 2012). A ploughing operation or herbicide application is considered a more powerful and instantaneous selection factor than most of the factors found in a natural, undisturbed forest (Malik *et al.,* 2007). A single method of weed control is rarely thus successful and usually there are a number of weed species with different life cycles and survival strategies present. To achieve the desired level of overall weed control a number of methods need to be used in combination (Gianesi, 2009).

In weed management programmes, a thorough survey is necessary to address the weed problems in farmers' fields and survey information is absolutely important in building target oriented research programmes (Hakim *et al.,* 2013). Beyond possible efficiencies related to accurate targeting of control measures, weed surveys may further improve ecological understanding of weed populations and thus encourage ecologically based management under the tenets of sustainable agriculture.

Unlike the much smaller size in agricultural field experiments, weed surveys may be more comprehensively interpreted because of the larger size of the area sampled and the consolidation of a "system" in given agroecological zones (Concenco *et al.,* 2013). Such studies are accordingly amenable to use of several synecological parameters that may be considered for the importance of each species in the system, namely: abundance, density, cover, frequency, homogeneity, dominance, and others. It is further important that farmer perspectives of their cultivation and weed control practices are carefully studied, documented and harmonized with collated scientific knowledge (Shemdoe *et al.,* 2008). Against orthodox recommendations aimed to eradicate them, farmers incorporate selected wild plants classified as weeds into their normal diet or as medicines (Maroyi, 2013). Thus, lessons derived at a socio-ecological landscape scale may be better suited to optimize effective sustainable farming.

The importance of the study was founded in terms of dominance of the maize crop as it accounts for more than 80 per cent of the total cropped area in Swaziland. This is equivalent to 70,000 ha of the total of 80,000 ha under rain-fed cultivation (Swaziland Government, 2005). In addition to biodiversity aspects, the up-dated information on weed infestation was aimed at farmers, advisory services and the agro-chemical industry, with a view to promoting specific weed control measures that could accompany tractor-based primary tillage technology. Our hypothesis was that attendant biophysical characteristics and continuous maize cultivation practices affect composition of the weed flora and level of weed infestation in Swaziland.

MATERIALS AND METHODS

Study area. Swaziland is divided into four agro-ecological zones, which run longitudinally North to South (Swaziland Government, 2016) (Figure 1). Sprawling West to East are the Highveld and the Middleveld with the latter further divided into upper and lower Middleveld due to the amount of precipitation received by the sub-zones. Further South is the Lowveld while the Lubombo Plateau is located to the extreme East of the country. The first three regions occupy about one third of the country each while the Lubombo Plateau represents only one tenth of the country. The survey was carried out in all the four agro-ecological zones and specific areas covered were: Ngwempisi and Ntfonjeni in the Highveld, Ngwenyameni and Sigombeni in the Upper Middleveld, Bhekinkhosi and Luve in the Lower Middleveld, Mdumezulu in the Lowveld and Tikhuba in the Lubombo plateau. The study areas were selected as representative of locations where smallholder farmers produce maize yearly. Table 1 shows important characteristics of the four agro-ecological regions.

The Highveld is characterized by a humid to near temperate climate where a variety of crops are grown and higher yields are usually obtained due to the high rainfall and moderate temperatures. Maize is the dominant crop and other crops grown include sweet potato and a variety of legumes (Remmelzwaal, 2006). The Middleveld climate is sub-tropical and is suited for the production of maize, beans, and cowpeas, groundnuts, pineapples and sweet potato. Drought tolerant crops such as cassava, sorghum and cotton are recommended for the dry Middleveld. The Lowveld has a semi-arid to arid climate and very prone to drought. Crops grown include cotton, citrus, and sugarcane, grown as an industrial crop under irrigation. The Lubombo plateau has a climate almost similar to the Middleveld. The main crops grown include maize, grain legumes, sorghum, sweet potato, cassava and cotton (Remmelzwaal, 2006). Livestock production is a major agricultural activity and cattle are the prime investment asset in much of Swaziland with households deriving both income and food from their free-range animals. According to the Annual Statistical Bulletin of 2014, cattle numbered 620,032 whilst there were 296 000 goats, 15 700 sheep, 36 700 pigs and 1.7 million poultry.

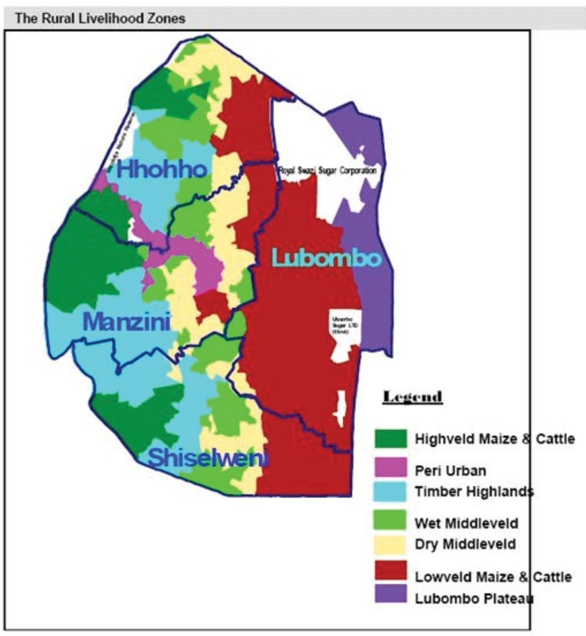

Figure 1. Map of Swaziland with the four agro-ecological zones and their sub-zones
Source: Food and Agriculture Organization (2008)

Table 1. Swaziland: characteristics of the main agro-ecological zones and smallholder production

Characteristics	Highveld	Middleveld	Lowveld	Lubombo Plateau
Elevation (masl)	900 - 1200	450 - 900	150 - 450	450 - 700
Rainfall (mm)	700 - 1550	550 - 850	400 - 550	550 - 850
Temperature (0C)	16	19	22	19
Soil type	Very deep soil formation of clay	deep and mostly red clay to clay loamy	red soil	deep and red medium to heavy texture
Major constraints	excessive leaching of nutrients; high soil acidity; low soil fertility	low soil fertility, high soil acidity and deficiencies in molybdenum	Saline soils and saline sodic soils; high temperatures and very prone to drought	Excessive leaching of nutrients; low soil fertility; high soil acidity
Area under maize (ha)*	16,630	28,506	13,976	7,438
Yield (t/ha)**	1.97	1.25	0.94	0.74

*Area planted under maize, 5-year average, 2009/10-2014/15
**Yield based on area under maize, 5-year average, 2009/10-2014/15
Source: Swaziland Government (2016)

Weed survey procedure. A survey of weed flora species in smallholder farmers' fields was carried out in March 2016 within the 2015/2016 cropping season at milking stage of the maize crop. At this stage, approximately three months would have elapsed after weeding or post-emergence herbicide application. The survey was conducted using two approaches: first by contacting farmers directly and inviting them to answer a questionnaire, and second, by sampling weeds from their fields to identify and evaluate the major weed species. In the first part, a total of 99 questionnaires were distributed to farmers to capture their perceptions, activities, knowledge, practices and identity of weed species on the basis of aggressiveness, difficult to control, and those that had become problematic in the past years. Aggressiveness referred to fast and vigorous growth in the early stages of growth of the weed so as to adversely affect early crop growth and development. Difficult to control referred to situations in which weed control by hand pulling, hoeing or use of ox-drawn cultivators was not easily accomplished.

The second part of the study was done according to the quantitative survey method using 1 m x 1 m size quadrate with six samples from each field modified from Salonen *et al.* (2011). From two out of six quadrats, weeds were counted and their density determined by counting the number of plants or shoots of grass weeds by species in each quadrat. Weed identification was based on botanical keys supported by regional field identification guides (Lightfoot, 1970; Vernon, 1983). Weed species diversity was determined using Shannon's index while the similarity of species composition between zones was compared using Jaccard's index (Magurran, 2004). Since Jaccard's index requires binary data, grasses and sedges (monocots) were pooled to form one set, while broadleaved weeds (dicots) formed the second set (Ngome *et al.,* 2012). Values of Jaccard's index range from 0 (not similar) to 1 (very similar). Relative abundance was used to rank the weed species in the survey (Thomas, 1985). The index allows comparison of weed communities prevalent in various years and locations. The value has no units but the value for one species in comparison to another indicates the relative abundance of the species (Thomas and Wise, 1987; Conceco *et al.,* 2013). The index was calculated as the sum of relative frequency, relative uniformity and relative mean field density for that species using the following formula (Thomas, 1985):
Relative Abundance (RA) = Relative Frequency (RF) + Relative Uniformity (RU) + Relative Density (RD)
Where:

- Relative Frequency (RF) = Count by weed species / Total weed count
- Relative Uniformity (RU) = Count of quadrats with a given weed species / Total number of quadrats

- Relative Density (RD) = Count of a given weed species / Total weed count

The frequency indicates the percentage of fields infested by a species and is an estimate of the geographical extent of the infestation. The uniformity indicates the percentage of quadrats infested by a species and is an estimate of the area infested by a weed. The density indicates the number of individuals of a species per square metre.

RESULTS AND DISCUSSION

Weed species taxonomy. A total of 34 weed species from 18 families were identified in the study areas. The majority of species identified were from the Asteraceae family (6 species), and Poaceae family (5 species), respectively, whereas *Solanaceae, Euphorbiaceae* and *Malvaceae* family had three species each, and *Convolvulaceae* and Laminaceae families had two species each. The rest of the families (*Amaranthaceae, Capparaceae, Commelinaceae, Cyperaceae, Fabaceae, Oxalidaceae, Portulacaceae, Rubiaceae, Scrophulariaceae*, and *Tiliaceae*) were observed to have only single species across study areas surveyed. In all the regions, *Commelina benghalensis, Richardia scabra, Xanthium strumarium, Acanthospermum hispidum, Bidens pilosa, Amaranthus hybridus, Tagetes minuta, Eleusine indica, Cynodon dactylon, Ipomoea purpurea, Cyperus esculentus, Corchorus olitorius, Sida rhombifolia, Convolvulus sagittatus, Nicandra phaseolus, Phyllanthus leucanthus, Cassia obstusifolia, Sida alba* and *Datura stramonium* were recorded. Table 2 summarizes the different weed species and the agro-ecological regions in which they were found.

Weed species diversity and communities. According to Conceco *et al.* (2013) a diversity index is a statistic which is intended to understand the variety of individuals of a given population thus allowing inferences about a particular plant community in terms of both the number of species found and the balancing in the number of individuals per species. Using Shannon diversity index (H'), the comparison of species diversity amongst the five agro-ecological regions in the study area showed that weed species in the Highveld tended to be the most diverse followed by the Upper Middleveld and the Lowveld. The Lower Middleveld and the Lubombo plateau exhibited lower weed species diversity (Table 3). The high Shannon-Wiener indices also indicated that no one species was dominant. This result is not in tandem with findings of Stohlgren (2007) for natural ecosystem who suggested that low productivity (high stress) areas usually present low diversity and also true for very productive sites, as a result of competitive exclusion. High diversity is usually observed in sites with intermediate productivity. In Swaziland, high maize yields are obtained in the Highveld and Middleveld owing to favourable rainfall regimes while considerably lower yields are obtained in the Lowveld and Lubombo Plateau (FAO/ WFP, 2015). Higher weed species diversity largely mirrored productivity of the Highveld and Upper Middleveld but this was not true for the other regions.

The Jaccard's index was used to compare weed communities across the five agro-ecological zones (Table 4). According to Booth *et al.* (2003), these indices are considered elevated when they are above 0.5 (50%), at which a high similarity can be interpreted between areas. The high values indicate less environmental heterogeneity and low values imply high environmental heterogeneity (Awodoyin *et al.,* 2013). Jaccard's index of similarity ranged from 0.58 to 0.94 amongst the agro-ecological zones studied (Table 4). While there was a greater similarity in weed communities between the Highveld and the Upper Middleveld and the least similarity between the Highveld and the Lowveld, the composition of the weed community in the five zones was not dissimilar according to the threshold given by the coefficient of Jaccard's index. The Jaccard index however only considers how many species are in-common in a pair of evaluated communities and does not take into account the abundance of each species (Ramirez *et al.*, 2012).

Abundance of weed species. Relative abundance provides an indication of the overall weed problem posed by a species (Ramirez *et al.,* 2012). The index quantifies the predominance of a given weed species in an environment by calculating the frequency, field uniformity, and density of a particular weed species relative to all other species observed. Twenty weed species out of 34 had a ranking in abundance in all five regions (Table 5). Of these, *Amaranthus hybridus, Acanthospermun hispidum, Bidens pilosa* and *Eleucine indica* had a ranking above 50 per cent across all regions. *Sida rhombifolia, Richardia scabra, Xanthium strumarium, Tagetes minuta*, and *Cynodon dactylon* had a ranking above 50 per cent

Table 2. Different weed species and their occurrence in five agro-ecological zones of Swaziland

Life forms	Latin name of the weed species	Highveld	Upper Middleveld	Lower Middleveld	Lowveld	Lubombo
Grasses						
Annuals	*Eleusine indica* (L.) Gaertn	+	+	+	+ +	
	Digitaria sanguinalis (L.) Scop	+	+	-	- -	
	Setaria verticillata (L.) P. Beauv		+	-	- -	-
Perennials	*Cynodon dactylon* (L.) Pers	+	+	+	+ +	
Sedges	*Cyperus esculentus* (L.)	+	+	+	+ +	
Broadleaves						
Annuals	*Portulaca oleracea* (L.)	+	+	-	+ -	
	Datura stramonium (L.)	+	+	+	+ +	
	Striga asiatica (L.) Kuntze	+	+	+	+ +	
	Sida alba (L.)	+	+	+	+ +	
	Amaranthus hybridus (L.)	+	+	+	+ +	
	Bidens pilosa (L.)	+	+	+	+ +	
	Ipomoea purpurea (L.) Roth	+	+	+	+ +	
	Convolvulus sagittatus (Thunb.)	+	+	+	+ +	
	Xanthium strumarium (L.)	+	+	+	+ +	
	Corchorus olitorius (L.)	+	+	+	+ +	
	Acanthospermum hispidum (DC.)	+	+	+	+ +	
	Nicandra physaloides (L.) Gaertn	+	+	+	+ +	
	Tagetes minuta (L.)	+	+	+	+ +	
	Phyllanthus leucanthus (Pax.)	+	+	+	+ +	
	Cassia obtusifolia (L.)	+	+	+	+ +	
	Cleome monophylla (L.)	+	+	+	+ +	
	Parthenium hysterophorus (L.)	+	+	+	+ +	
	Galinsoga parviflora (Cav.)	+	+	+	+ +	
	Schkuhria piñnata (Lam.) Kentze ex Thell	+	+	-	+ -	
	Leucas martinicensis (Jacq.)	+	+	-	+ -	
	Solanum inacum (L.)	+	+	-	- -	
	Euphorbia hirta (L.)	+	+	-	- -	
	Triumfetta neglecta (Wight and Arn.)	+	+	-	- -	
	Euphorbia heterophylla (L.)	-	-	+	- -	
Biennials	*Hibiscus cannabis* (L.)	+	+	-	+ -	
Perennials	*Oxalis latifolia* (Kunth)					
	Commelina benghalensis (L.)	+	+	+	+ +	
	Sida rhombifolia (L.)	+	+	+	+ +	
	Richardia scabra (L.)	+	+	+	+ +	

Where (+) signifies presence of weed species and (-) absence of weed species
Source: Weed Survey Data (2016)

Table 3. Weed species diversity based on the Shannon diversity index (H') values in five agro-ecological zones of Swaziland

Agro-ecological zone	Shannon diversity index (H') values
Highveld	3.11
Upper Middleveld	2.96
Lower Middleveld	2.77
Lowveld	2.82
Lubombo	2.75

Source: Weed Survey Data (2016)

Table 4. Weed species similarity based on Jaccard indices in five agro-ecological zones of Swaziland

Agro-ecological zone	Highveld	Upper Middleveld	Lower Middleveld	Lubombo Plateau	Lowveld
Highveld	1.00	0.94	0.68	0.82	0.58
Upper Middleveld		1.00	0.70	0.84	0.59
Lower Middleveld			1.00	0.85	0.86
Lubombo Plateau				1.00	0.74
Lowveld					1.00

Source: weed survey (2016)

in four of five regions. Sixteen species, amongst the 20 weed species prevalent across the five regions, had a ranking above 50 per cent in one or more regions. In addition, the regions appeared to share similar weed species ranked above 50 per cent abundance. The Highveld and Upper Middleveld had the largest number of weed species showing a weed flora more compatible with the soil and climate conditions. The possible reason for the abundance of *Richardia scabra* in the Lubombo according to farmers is that, it is mainly spread by the tractors hired by farmers to prepare their land as the weed was initially not present in the region. Tractors may thus carry all kinds of weeds from one region to another perpetuating their spread. Another possible reason attributed for the abundance of *Eleusine indica* in the Lowveld was that being a forage grass which is consumed by cattle, its seed is readily spread through dung.

In order to make inferences about management practices, Conceco *et al.* (2013) suggested that abundant species are those widely distributed in an area; hence the application of pre-emergence herbicides, for instance, would play an important role in reducing their occurrence. As less frequent species occur in specific locations of the field, in many cases, there should be no need to apply the control all over the area in order to eliminate these species.

Weed management practices. Weed management data were collected in order to relate to weed data. Weed control was done manually by 53% of the farmers while 20% combined manual and mechanic control, 17% used herbicides and 10% used a combination of herbicide and manual control. Farmers used either hoes or tractor-drawn cultivators for mechanical weed control. When asked the least preferred method of weed control, 52% mentioned manual weeding, the remainder mentioned use of herbicides and cited a number of reasons shown in Table 6. Farmers however lauded herbicides as being less labour intensive compared to manual weeding and that they obtained higher crop yields due to absence of weeds for the duration of the crop. Manual methods were also favoured wherein they allow intercropping and coverage of crop roots, and were considered cheaper. Post-harvest weed control and management of headlands were practiced by 82% and 80% of the farmers, respectively (Table 6). The methods, merits and reasons for denigration of practices are summarized in Table 6.

The prevailing weed control problems that concern farmers led to various suggestions on how weed control could be improved. Some of the potential strategies included the introduction of integrated weed control through the use of manual and herbicide use (62%), weeding twice (24%), application of pre-emergence herbicides (7%), post-harvest weed control using disc-plough (4%), post-harvest weed control using herbicides (1%), use of non-selective herbicides (1%), and an early weeding (1%). They indicated that these improved strategies could be communicated and popularized in their communities through training and demonstrations that should include chemical weed control.

Weed persistence in farmers' fields. Farmers were asked to account for persistence of weeds in their fields. Animal manure which is the main source of crop nutrients in farmers' fields was cited as the main carrier and foundation of weed seeds. In the areas of study, farmers prepare their land using tractors hired from private owners or under the public tractor hire scheme. Farmers faulted these tractors as carriers and dispersers of weeds as they prepared land from one area/ region to another. This practice, they claimed, has resulted in certain areas experiencing problematic weeds which they did not have in the past years. Another cause of weed persistence cited was improper land preparation practices. Farmers believed that land preparation that excludes disc ploughing and harrowing tended to result in early germinating weed flora that becomes very

Table 5. Relative abundance of weeds in five agro-ecological zones of Swaziland

	Latin name of the weeds species	Highveld	Upper Middleveld	Lower Middleveld	Lubombo	Lowveld
1.	*Striga asiatica*	44	52	67	39	53
2.	*Sida alba*	30	37	50	48	52
3.	*Commelina benghalensis*	98	95	59	29	19
4.	*Sida rhombifolia*	68	72	72	36	61
5.	*Amaranthus hybridus*	68	77	72	58	65
6.	*Ipomoea purpurea*	70	41	45	36	25
7.	*Richardia scabra*	49	95	68	77	84
8.	*Convolvulus sagittatus*	27	41	43	53	37
9.	*Xanthium strumarium*	75	93	53	54	47
10.	*Corchorus olitorius*	68	56	44	38	29
11.	*Cyperus esculentus*	39	73	76	66	43
12.	*Acanthospermum hispidum*	72	87	82	57	73
13.	*Nicandra phaseoloides*	39	31	34	30	24
14.	*Bidens pilosa*	66	76	50	65	78
15.	*Tagetes minuta*	34	62	50	56	60
16.	*Eleusine indica*	59	87	80	72	90
17.	*Cynodon dactylon*	73	76	48	74	88
18.	*Phyllanthus leucanthus*	39	30	36	44	33
19.	*Cassia obstusifolia*	20	18	39	18	21
20.	*Datura stramonium*	32	85	23	27	52
21.	*Cleome monophylla*	18	44	26	25	-
22.	*Parthenium hysterophorus*	36	87	46	23	-
23.	*Galinsoga parviflora*	32	41	32	21	-
24.	*Portulaca oleracea*	21	25	-	11	-
25.	*Schkuhria pinñata*	16	37	-	15	-
26.	*Leucas martinicensis*	55	36	-	9	-
27.	*Hibiscus cannabis*	34	43	-	17	-
28.	*Digitaria sanguinalis*	17	68	-	-	-
29.	*Solanum incanum*	9	46	-	-	-
30.	*Oxalis latifolia*	35	49	-	-	-
31.	*Euphorbia hirta*	14	26	-	-	-
32.	*Triumfetta neglecta*	18	85	-	-	-
33.	*Setaria verticillata*	28	-	-	-	-
34.	*Euphorbia heterophylla*	-	-	22	-	-

competitive with crops thus reducing yields. Other farmers claimed that lack of post-harvest weed management contributed significantly to the weed flora.

Problematic weeds in farmers' fields. An important objective of noxious weed management is to reduce the spread of serious weeds and to prevent their introduction from adjacent geographic areas. It is thus essential to assess which weed species are problematic and to set priorities with regard to developing weed management strategies. Farmers were asked to list five most problematic weeds in their fields and the results are detailed in Table 7.

Cynodon dactylon was considered the most problematic weed throughout the regions. The weed reproduces using rhizomes thus it tends to spread quickly in the field upon cultivation. *Xanthium strumarium* was the second most problematic weed and highly problematic in the Lower Middleveld and Lowveld. *Bidens pilosa* was the third most problematic weed especially in the Upper Middleveld. The fourth troublesome weed was *Richardia scabra*, problematic in all regions but mostly in the plateau. The fifth most problematic weed was *Commelina benghalensis* highly problematic in the Upper Middleveld. Farmers acknowledged that they let weeds to flower in the field which results in addition of weeds to the seedbank and consequently the next seasons weed flora dominated by such weeds. Regardless of the ranking, it was noted that these weeds including *Amaranthus hybridus, Cyperus esculentus, Striga asiatica* and *Eleusine indica,* remain a problem across all regions in Swaziland.

Difficult to control weeds in farmers' fields. *Cynadon dactylon* was reportedly the most difficult to control weed species in the Highveld and Upper Middleveld based on farmer responses (Table 8). In the Lower Middleveld and Lowveld *Xanthium strumarium* was the most difficult to control while in the Lubombo region, *Richardia scabra* was the most difficult to control weed species. According to farmers, these weeds tend to grow in dense stands, spread and infest fields in large patches and subsequent generations always came up soon after removal of one generation.

Aggressive weeds in farmers' fields. Table 9 shows *Richardia scabra* as the most aggressive weed in all the regions. Information gathered during the field survey revealed that this weed had been on the increase in all the regions. *Xanthium strumarium* was the second most aggressive weed in all the regions. This could be attributed to the presence of the weed seed in manure thus perpetuating its vigorous growth in the field. *Cynodon dactylon* was the third most aggressive weed. Most farmers interviewed in the regions reported that once the land is ploughed and the weed is exposed to the dry weather it easily succumbs to the hot temperatures. Thus farmers reported high infestation levels in the Highveld, Lubombo plateau and Upper Middleveld and low infestation levels in the Lower Middleveld and Lowveld the latter locations that subtend high annual temperatures.

Early germination and plasticity are attributes of highly competitive plants (Aldrich, 1984) and these characteristics are found in most of the weeds listed as aggressive and difficult to control in this survey. Some of these weeds, such as *Xanthium strumarium* have irregular germination which makes control difficult because they germinate throughout the whole year (Chivinge, 1988). Most farmers cannot weed when it is too wet because they either hand-hoe or cultivate with ox-drawn implements. This increases infestation by weeds with big root systems

Table 6. Weed control methods used by farmer

Preference of weed control methods					
Manual weeding least preferred			Herbicide least preferred		
Reason	*n*	%	Reason	*n*	%
Labour intensive	50	50.5	Expensive	18	18.2
Time consuming	1	1.0	Contaminates soil	8	8.1
			Lack of knowledge on its application	7	7.1
			Inability to intercrop with pumpkins	6	6.1
			Destroys maize	5	5.1
			Selects broadleaf weeds only	4	4.0
Total	51	51.5		48	48.5
Post-harvest weed management					
Practice post-harvest weed management (sd=0.517)			Do not practice post-harvest weed management (sd=1.064)		
Reason	*n*	%	Reason	*n*	%
Grazing of animals	64	64.6	No need	8	8.1
Disc plough	15	15.2	Saving costs	4	4.0
Slashing	3	3	Not important	3	3.0
			Labourous	2	2.0
Total	82	82.8		17	17.2
Management of headlands					
Manage headlands (sd=0.615)			Do not manage headlands (sd=0.851)		
Method used	*n*	%	Reason	*n*	%
Use of slashers	47	47.5	No attention given	10	10.1
Burning	30	30.3	Prevents erosion	4	4.5
Plant fruit trees	2	2.0	Grass used for thatch	4	4.5
Apply herbicides	1	1.0			
Total	80	80.8		19	19.2

Table 7. The most problematic weeds in different agro-ecological zones in Swaziland

Latin name of the weeds	Highveld (n=27)		Upper Middleveld (n=17)		Lower Middleveld (n=17)		Lubombo Plateau (n=25)		Lowveld (n=13)		Total (n=99)
	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Cynodon dactylon	22	81	7	41	9	53	12	48	7	54	57
Xanthium strumarium	12	44	3	18	17	100	11	44	12	92	55
Bidens pilosa	9	33	14	82	2	12	11	44	8	62	44
Richardia scabra	7	26	3	18	10	59	16	64	5	39	41
Commelina benghalensis	9	33	11	65	1	6	1	4	2	15	24
Amaranthus hybrydus	8	30	2	12	2	12	4	16	6	46	22
Cyperus esculentus	10	37	1	6	2	12	7	28	1	8	21
Striga asiatica	9	33	1	6	3	18	1	4	3	23	17
Eleusine indica	5	16	4	24	3	18	1	4	0	0	13

Source: weed survey (2016). Where No. = Number of responses

Table 8. The most difficult to control weeds in each agro-ecological zone in Swaziland

Latin name of the weed	Highveld (n=27)		Upper Middleveld (n=17)		Lower Middleveld (n=17)		Lubombo Plateau (n=25)		Lowveld (n=13)		Total (n=99)
	No.	%	No.	%	No.	%	No.	%	No.	%	No.
Cynodon dactylon	15	56	8	47	6	35	10	40	5	39	44
Richardia scabra	3	11	5	29	8	47	14	56	4	31	34
Xanthium strumarium	6	22	1	6	11	65	3	12	8	62	29
Cyperus esculentus	8	30	2	12	2	12	3	12	1	7	16
Commelina benghalensis	2	7	8	47	1	6	0	0	1	8	12
Acanthospermum hispidum	2	7	0	0	2	12	2	8	1	8	7
Striga asiatica	3	11	0	0	1	6	0	0	1	8	5

Source: weed survey (2016). Where No. = Number of responses

Table 9. The most aggressive weed in each agro-ecological zone in Swaziland

Latin name of the weed	Highveld (n=27)		Upper Middleveld (n=17)		Lower Middleveld (n=17)		Lubombo Plateau (n=25)		Lowveld (n=13)		Total (n=99)
	No.	%	No.	%	No.	%	No	%	No.	%	No.
Richardia scabra	6	22	4	24	7	41	14	56	5	59	36
Xanthium strumarium	8	30	3	18	11	65	6	24	8	62	36
Cynodon dactylon	12	44	6	35	2	12	9	36	3	23	32

Source: weed survey (2016). Where No. = Number of responses since they are difficult to remove by these methods of weeding.

Troublesome weeds. The weed species that were mentioned by farmers as problematic, difficult to control and aggressive, respectively, were defined as the most troublesome using farmers' evaluation. The weed species, *Cynodon dactylon, Richardia scabra*, and *Xanthium strumarium*, qualified as the most troublesome as they appeared under each of the three categories as mentioned by farmers. This agrees with their relative abundance ranking of above 50 per cent in four of five regions. Although the species *Cyperus esculentus* and *Striga asiatica* only appeared in two categories, as problematic and difficult to control weeds, their being listed by farmers demonstrates the need to recognize them as potential intractable weeds.

Our criteria for evaluating economically important weeds in maize production can be juxtaposed to that considered by farmers in Kenya (Ngome *et al.,* 2012). Theirs comprised: (i) abundance (percentage coverage in maize fields, e.g. *Bidens pilosa*), (ii) aggressiveness (capacity to establish and compete effectively with maize), (iii) persistence (ease of propagation and regeneration, e.g., *Commelina benghalensis*) and (iv) presence of irritating substances (pines, thorns, stiff hairs) that affect manual weeding.

Un-weeded weeds. In all the regions, farmers reported that during the weeding period, they do eliminate some weeds and leave others unharmed. However, compared to other studies in East and Southern Africa (Hillocks, 1998), Tanzania (Shemdoe *et al.,* 2008) or Thailand (Cruz-Garcia and Price, 2012), a rather narrow range of species in cultivated fields were reported as providing leafy vegetables to the diet. *Corchorus olitorius* was reported as the most unweeded weed especially in the Highveld, followed by *Amaranthus hybridus* and *Bidens pilosa*. Other weeds such as *Commelina benghalensis* and *Sonchus oleraceus* were also reported as important vegetables in this survey. Earlier studies reported *Bidens pilosa* as the most frequently consumed wild leaf vegetable and eaten by more than 70% of the adult population in Swaziland (Ogle and Grivetti, 1985).

In the present study, farmers did not consider un-weeded weeds as interfering with growth and yield of maize. They claimed that the weeds were not intentionally left throughout the fields; rather their occurrence in patches facilitates their non-removal in those areas. Hillocks (1998) suggested that weed control within an integrated crop protection system should consider the vegetational diversity of smallholder agriculture to which weeds make their contribution, providing a source of secondary foods, medicines and insecticides.

CONCLUSION

The results of this study provide a quantitative comparison of the common weed species in Swaziland. In this survey, 34 weed species were identified and 20 species were found to be abundant in all regions. *Cynodon dactylon, Richardia scabra* and *Xanthium strumarium* were the most problematic, difficult to control and aggressive weeds. *Corchorus olitorius* was the common weed left un-weeded by farmers due to its contribution to farmers' diets.

The ranges of weed species recorded suggest the need for improved management of the established weeds for greater agroecosystem health. In addition, weeds identified by farmers that overlap with the computed weed community structure require incipient control, i.e., management approaches with the goal of complete suppression as quickly as possible which is the case with highly troublesome weed species.

It was noted that there were subtle differences in weed species diversity across the regions based on measures of diversity indices. The lack of distictiveness of the weed communities agree with the results of the species inventory (relative abundance) because it revealed that the breadth of the weed problem was represented by the same species in all of the agroecological zones of Swaziland.

Farmers identified their areas and fields as subject to weed invasion from practices such as the tractor-pool scheme or communal animal grazing. An in-depth follow-up study will provide an understanding of the biology of the invasion process and permit development of weed management plans.

Weed control in Swaziland is done both manually and using herbicides. However, farmers still face the daunting problem of weeds. Data on weed species abundance are not direct indicators for yield losses caused by individual weed species or weed complexes. Such data, however, in combination with information on specific problems in temporal and spatial weed control, as ably elucidated by farmers, provide sufficient proposition for response to farmers' request for training on weed control techniques including herbicide use premised on integrated control principles and practices. This study thus benefited from more questions about the roles and activities of those being surveyed, the farmers.

ACKNOWLEDGMENTS

We thank the anonymous reviewers for their comments on various drafts. We also thank the people who helped us locate fields, and especially the farmers who allowed us to survey their fields. This study was funded through the Graduate Research Grant Call ID RU/CGS/GRG/21/07/14 of the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM).

STATEMENT OF NO CONFLICT OF INTEREST

We the authors of this paper hereby declare that there are no competing interests in this publication.

REFERENCES

Aldrich, R. J. 1984. Weed-Crop Ecology: Principles in Weed Management. North Scituate MA, Breton Publishers. 465pp.

Awodoyin, R. O., Akinyemi, C. Y., Bolanle, O. O. and Antiabong, I. C. 2013. Spatial distribution and abundance of *Solanecio biafrae* (olive and heirne) c. jeffrey and structure of weed communities in some cocoa plots in Ekiti, Oyo and cross river states, Nigeria. *Ife Journal of Science* 15 (3): 661-676.

Booth, D. B., Murphy, S. D. and Swanton. C. J. 2003. Weed ecology in natural and agricultural systems. CABI Publishing, Wallingford, United Kingdom.

Chivinge, O. A. 1988. A weed survey of arable lands of the small-scale farming sector of Zimbabwe. *Zambezia* 15 (2): 167-179.

Concenço, G., Tomazi, M., Correia, I., Santos, A. and Galon, L. 2013. Phytosociological surveys: Tools for weed science. Levantamentos Fitossociológicos: Ferramentas para a Ciência das Plantas Daninhas. *Planta Daninha, Viçosa-MG* 31 (2): 469-482.

Cruz-Garcia, G. and Price, L. L. 2012. Weeds as important vegetables for farmers. *Acta Societatis Botanicorum Poloniae* 81 (4): 397-403.

Food and Agriculture Organisation / World Food Programme. 2008. FAO global information and early warning system on food and agriculture world food programme. Special report. 4 July 2008. Mbabane, Swaziland.

Food and Agriculture Organisation/ World Food Programme (FAO/WFP). 2015. FAO/ WFP Crop and food security assessment mission to Swaziland. Special Report. 24 July 2015. Mbabane, Swaziland.

Gianesi, L. 2009. Solving Africa's weed problem: increasing crop production and improving the lives of women. Crop Protection Research Institute, Croplife Foundation. http://www.croplifefoundation.org

Hakim, M. A., Juraimi, A. S., Ismail, M. R., Hanafi, M. M. and Selamat, A. 2013. A survey on weed diversity in coastal rice fields of Sebarang Perak in Peninsular, Malaysia. *The Journal of Animal and Plant Sciences* 23 (2):534-542.

Hillock, R. J. 1998. The potential benefits of weeds with reference to small holder agriculture in Africa. *Integrated Pest Management Reviews* 3 (3): 155-167.

International Relief and Development (IRD). 2012. Lowveld baseline and vulnerability assessment. Reduction of drought vulnerabilities in southern Swaziland. Mbabane, Swaziland.

Lightfoot, C. 1975. Common veld grasses of Rhodesia. Natural Resources Board of Rhodesia. Harare, Zimbabwe.

Magurran, A. E. 2004. Measuring biological diversity. Oxford: Blackwell Publishing. Oxford, UK.

Malik, N. Z., Arshad, M. and Mirza, S. N. 2007. Phytosociological attributes of different plant communities of Pir Chinasi hills of Azad Jammu and Kashmir. *International Journal of Agricultural Biology* 9 (4): 569-574.

Maroyi, A. 2013. Use of weeds as traditional vegetables in Shurugwi District, *Zimbabwe Journal of Ethnobiology and Ethnomedicine* 9 (60): 1-10.

Ngome, A. F., Mtei, K. M., Mussgnug, F. and Becker, M. 2012. Management options and soil types differentially affect weeds in maize fields of Kakamega, Western Kenya. *Journal of*

Agricultural Science and Technology 2 (1):104-114.

Ogle, B. M. and Grivetti, L. E. 1985. Legacy of the chameleon: edible wild plants in the Kingdom of Swaziland. A cultural, ecological and nutritive study. Part II ± Demographics, species availability and dietary use, analysis by ecological zone. *Ecology of Food and Nutrition* 17 (1): 1-30.

Radosevich, S., Holt, J. and Ghersa, C. 1997. Weed ecology. 2nd edition. Harper and Row Publishers . USA. New York.

Ramírez S. J., Hoyos, V. C. and Guido Plaza, T. A. 2015. Phytosociology of weeds associated with rice crops in the Department of Tolima, Colombia. *Colombiana* 33 (1): 64-73.

Remmelzwaal, A. 2006. Swaziland country environment profile. Mbabane, Sw aziland.

Salonen, J., Hyvonen, T. and Jalli, H. 2011. Composition of weed flora in spring cereals in Finland – a fourth survey. *Agricultural and Food Science* 20 (3): 245-261

Shemdoe, R. S., Mbago, F. M., Kikula, I. S. and van Damme, P. L. 2008. Weed species diversity on arable land of the dry land areas of central Tanzania: impacts of continuous application of traditional tillage practices. *Geography Journal* 71 (2-3):107–115.

Singh, A. and Dangwal, L. 2013. A survey of weed flora in maize fields of district Rajouri (J and K), India. *International Journal of Scientific Research* 2 (1): 6-9.

Swaziland Government. 2016. Ministry of Agriculture. Mbabane, Swaziland. http://www.gov.sz/index.php?optio=com Accessed 09/05/2016 .

Swaziland Government. 2005. Support to NEPAD–CAADP Implementation. Community–based natural resources and land management. New Partnership for Africa's Development (NEPAD) and Food and Agriculture Organization of the United Nations. Mbabane, Swaziland.

Thomas, A. G. 1985. Weed survey system used in Saskatchewan for cereal and oilseed crops. *Weed Science* 33 (1): 34-43.

Thomas, A. G. and Wise, R. F. 1987. Weed survey of Saskatchewan for cereal and oilseed crops. Weed survey series. Pub. 87-1. Agricultural Canadian Regina, Saskatchewan. pp. 251.

Vernon, R. 1983. Field guide to important arable weeds of Zambia. Chilanga, Zambia: Mount Makulu Central Research Station, Department of Agriculture.

Zimdahl, R. 2007. Fundamentals of weed science. 3rd edition. Academic Press, New Delhi, India.