ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 6, Issue 1, pp: (109-118), Month: January - March 2018, Available at: www.researchpublish.com

Bioinvasion Assessment of Sedges: Cyperus Spp. in the Philippine Agricultural System

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Abstract: **Forage flora are plants in grass and grass-like structure and are utilized as food source by animals whether fresh or processed. This study aimed assess the bioinvasion of *Cyperus species* in the rice producing provinces in the Philippines. On the other hand, Bioinvasion and Qualitative Risk assessment established the distribution and effects of the *Cyperus species* in the Philippine Agricultural system. Moreover, the ODA Qualitative Risk assessment tool and Bioinvasion tool established sedge distribution.**

Studies on the distribution of sedges in the country are very limited. This study identified 14 Cyperus species found in the Provinces of Masbate, Tarlac, Nueva Viscaya and Isabela. Thirteen (13) of which are considered as weeds while the other one as ornamental species. *Cyperus species* identified as world's worst weeds are found growing in the country, nevertheless new species (*Cyperus distans L.*, *Cyperus compactus* L f., *Cyperus cyperoides* and *Cyperus imbricatus* Retz.) were also found to be locally invasive in some Provinces. Ninety three (93%) or 13 out of the 14 identified *Cyperus species* are found inhabiting the agricultural system of the country.

Keywords: **Diversity, Forage Flora, Sedges, Bioinvasion, *Cyperus spp.***

I. INTRODUCTION

Bioinvasion Assessment in the Agricultural Systems of the Rice producing Provinces in the Philippines: The Case of *Cyperus species* presents a more reliable assessment of the distribution, diversity, invasiveness and effects of *Cyperus species* in the agricultural systems of the country. The study created a field guide of forage flora both for instructional purposes for students as well as extension purposes for farmers.

According to James (2008), Philippines is one of the world's biotech mega-countries growing more than 50,000 hectares of biotech crops. It is accordingly an agriculture-dependent country meanwhile 1/3 or 30,000 M ha of its land is considered an agricultural land (BAS, 2004). Agriculture has contributed 20% to the country's gross domestic product (GDP), 24% to total export earnings, 40 % to total employment in the last 15 years (BAS, 2003).

Lima et al.. (2015) cited that weeds are major biotic components of agro-ecosystem that are capable of negatively interfering with crops. Lorenzi (2006) as cited by Lima et al.(2015) stipulated that weed interference on agricultural crops is responsible on average for yield reductions around 20 to 30% in Brazil.

Philippines being one of the most biodiverse countries in the world is not exempted from the existence of invasive weed species. Their occurrence have been observed both in wet and dry agricultural areas and protection forest based on the UNEP (2013) report. However, same report mentioned that most of the data are anecdotal and not scientifically or vigorously studied.

Moreover, CABI records showed that information on origin and category of *Cyperus sp.* as invasive weeds in the Philippines has not fully been established. Hopkins & Huner (2004) mentioned that Cyperaceae is a highly competitive weed capable of persisting in varied intense terrestrial environment (drought, high light, high temperature).

Table 1. Studies on *Cyperus species* cause and effect in other countries

FACTOR	CAUSE-EFFECT	SOURCE
ECONOMIC	60-70% total biomass loss on rice/12-50% reduction in rice grain yield	Ampong_Nyarko & Dedatta, 1991
	Yield loss due to effects of *C. difformis* in tiller number	Yu, 1992
	Invasion of crop lands as weeds (cotton, sugarcane & other crop fields) Competition of crops with Cyperaceae for light, nutrients, water and space. Herbicide resistance Interference or competition with crops and forest, cost of pest control, cultural-control practices, etc.	Bryson & Carter, 2008; Bryson, 2003; Holm et al.,1977; Westbrooks,2001; Chandler et al.,1984; Chandler & Cooke, 1992; Byrd,1995; Radosevich & Holt, 1984; Mcwhorter & Bryson,1992; Bryson et al. 1999; Hesla et al. 1982) Pappas-Fader et al.,1993;1994; Hill et al. 1994;Morales & Payan, 2005; Boyette,2000; Duke & Boyette, 2001. (Chandler et al.,1984; Chandler & Cooke,1992).
ENVIRONMENT/ HEALTH	Additional cost to human and animal health due to allergies and toxins Solid pollutants/particulates(seeds, achenes, silky bristle and hairs (allergens)	Bryson & Carter ,2008; Goetghebeur,1998; Hanes & Lye,1983
	Pathogen Host: Host to pest of rice (Root Knot nematode Eggs of stem borer Node feeding black bug Brown plant hopper Larvae of rice leaf folder (before migrating to rice) Causes sheath rot (rice) Sheath Blight	Ato et al., 1988 Alghali, 1979 Barrion & Litsinger, 1987 Chu & Yang, 1984 Joshi et al., 1985 Balakrishnan & Nair, 1981. Bandara & Nadaraja, 1979. Pomella & Barretto, 1997
	Cosmopolitan distribution	Simpson et al.,2003; Muasya et al.,2000 Moody et al.,1984; Govaerts, 2014
	Obstruct water ways creating dense colonies; impact native vegetation	Holm et al.,1979; USDA-NRCS,2014
	Allelopathic effect to crops (wheat, corn, rice, banana & other weeds	Martinez-Diaz, 1997; Carter, 1990; Bryson,1996, 2008; Alam & Azmi, 1991; Porwal & Mundra, 1992; Chou Chang & Ming Yang, 1992; Hamayun et al.,2005; Quayyum et al., 2000; Singh et al., 2009
TRANSPORT	Dispersion by transport through shipments, vehicles	Sell & Murrell,1996; Carter & Mears,2000
AESTHETIC/ INDUSTRY	Collection of Sedge species as ornamentals	Carter & Bryson, 2008
PHARMACOLOGICAL/NUTRITIONAL	Possessed good physico-chemical properties and high values of nutritionally valuable minerals (fatty acid, iodine, Copper, magnesium, potassium, calcium)Staple food (oil, carbohydrate, fibre, minerals	Oladunni, et al., 2011; Messiaen, 1992;

Source: Bryson & Carter, 2008; Oladunni et al., 2011.

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The *Cyperus Species:*

Cyperaceae is a cosmopolitan family with about 6,000 species and 100 genera that includes important global ecological, economic and horticultural significant species (Table 1). *Cyperus species* are also known as sedges (Ball et al., 2002; Goetghebeur, 1998; Simpson & Inglis, 2001). It has been reported in more than 90 countries infesting at least 52 different crops worldwide (Holm et al., 1977).

Sedges form a major component of most wetland vegetation units around the world and make an enormous contribution to nutrient cycling and habitat formation in these ecosystems (Harper, 1992; Chamber's et al., 2008). Both Goetghebeur (1998) and Simpson and Inglis (2001) mentioned that genus Cyperus specifically with around 600 species is another well-known genus that includes important economic and horticultural species.

Mack et al. (2000) however, stipulated that plant invasiveness involves a wide range of ecological and economic consequences, but in general, invasive plants are species that establish and spread outside their native range or management area and degrade the environment. On the other hand, Qasem (1994) & (2001) emphasized that many noxious annual and perennial weeds have been regarded as a species with allelopathic potential and can severely affect crop survival and productivity.

II. MAJOR FORMAT GUIDELINES

Table 2. Existing *Cyperus species* in the Rice producing Provinces in the Philippines

Species	Common Name	Classification	Distribution
Cyperus rotundus L.	Purple nut sedge	Perennial	Bicol Region, Tarlac, Nueva Viscaya, Isabela
Cyperus esculentus L.	Yellow nut sedge	Perennial	Bicol Region, Tarlac, Nueva Viscaya, Isabela
Cyperus difformis L.	Umbrella sedge	Annual	Bicol Region, Tarlac, Nueva Viscaya, Isabela
Cyperus iria L.	Rice Flat sedge	Annual	Bicol region, Tarlac, Nueva Viscaya, Isabela
Cyperus involucratus Rottboll	Ornamental sedge	Perennial	Bicol Region, Tarlac, Nueva Viscaya, Isabela
Cyperus imbricatus Retz.	Shingle flat sedge	Perennial	Masbate, Nueva Viscaya
Cyperus compactus Retz.	----------	Perennial	Masbate
Cyperus distans L. f	Slender Cyperus	Perennial	Masbate
Cyperus odoratus L.	Fragrant sedge/Rusty flat sedge	Annual/ Perennial	Masbate,Nueva Viscaya, Isabela
Cyperus cyperoides L. Kuntze	----------	Perennial	Masbate
Cyperus compressus L.	Annual sedge	Annual	Masbate
Cyperus kyllinggia Endl.	Button sedge	Annual	Bicol region, Nueva Viscaya, Tarlac, Isabela
Fimbristylis miliaceae L. Vahl	Golden globe rush	Annual/ Perennial	Bicol region, Nueva Viscaya, Tarlac, Isabela
Fimbristylis dichotoma L.Vahl	Forked flowered rush	Annual	Bicol region, Nueva Viscaya, Tarlac, Isabela

There are 14 identified *Cyperus species* found in the Provinces of Masbate, Tarlac, Nueva Viscaya and Isabela(Table 2). All of the 14 identified species are found in Masbate while others are amply distributed in other areas. However, *Cyperus compactus*, *Cyperus distans*, *Cyperus cyperoides* and *Cyperus compressus* were specifically observed only in Masbate.

IRRI (1997) mentioned that irrigated and lowland systems comprise ≈ 55% of the total rice area and provide 70% of global rice production, while rainfed lowland and flood-prone areas constitute ≈ 35% of the total rice area, covering 47 M ha in Asia but providing only, 25% of global rice production because of various abiotic challenges associated with rainfed ecosystems.

Rice farmers in rainfed and irrigated areas are shifting to direct seeding from transplanted rice as it provides opportunities to reduce costs and can result in earlier harvest (Balasubramanian & Hill, 2002). However, it enhances high weed infestation

(Du & Tuon, 2002). However, it enhances high weed infestation according to Du & Tuon (2002). Rao et al.(2007) stipulated that weeds constitute a major problem for the large-scale adoption of the direct- seeded rice, with yield losses of ~ 20% of attainable yield or even total loss if not controlled.

Weeds have a major economic importance for rice production in South and SouthEast Asia, and their control constitutes up to 30% of the total production cost. More than 1800 plant species were reported as weeds of rice in Asia according to Moody (1989). Rao, et al. (2007) identified Cyperaceae and Poaceae as the predominant species.

Aquatic weeds and those well adapted to flooded soils are major problems in lowland rice fields. In the Philippines, the cultivation of lowland rice in rotation with upland crops and vegetables in the same fields has resulted in the selection of ecotypes of "lowland" weeds such as *Cyperus rotundus* that can tolerate flooded soil (Peña-fronteras et al. 2009, Fuentes et al. 2010).

Donayre et al. (2016) found out that Cyperaceae are among the major groups of pests that farmers consider as a limiting factor in rice production. It can cause 44-96% rice yield reduction, competition for nutrients, sunlight, and water and can serve as alternate host for disease-causing pathogens and other pests of rice.

Ismail et al. (2012) identified *E. crus-galli* as one of the most widespread Poaceae. Among the world's worst weeds are *E. crus-galli*, *E. colona*, *C. difformis*, *C. iria* and *F. miliaceae* (Holm et al. 1977). This study however, was not able to document the presence of *C. rotundus* ecotypes in lowland areas. This can be attributed to the fact that the chosen study sites do not practice crop rotation between rice and vegetables in their farm. The major commodities planted in the areas are rice and corn where they have separate fields.

Table 3. Bioinvasion Assessment of Cyperus species in the Philippine Agricultural System

Scientific Name	TOTAL SCORE	INTERPRETATION
Cyperus esculentus	30	**HI**
Cyperus rotundus	31	**HI**
Cyperus difformis	24	SI
Cyperus iria	23	SI
Cyperus imbricatus	31	**HI**
Cyperus involucratus	21	NI
Fimbristylis milliaceae	22	SI
Cyperus kyllingia	20	NI
Cyperus distans	23	SI
Cyperus compactus	28	**HI**
Cyperus odoratus	23	SI
Fimbristylis dichotoma	24	SI
Cyperus cyperoides	20	NI
Cyperus compressus	23	SI

Legend: NI(Not Invasive); SI (Slightly Invasive); HI(Highly Invasive)

Majority of the rice farmers of Masbate make use of direct seeding and few have rice fields for commercial purposes thus, this can be attributed to the high incidence of Cyperus species infestation in many municipalities. Dependence to chemical control is limited since many farmers products are for home consumption only due to limited farm space.

On the other hand, Peña-Fronteras et al. (2009), reasoned out that the tolerance of *C. rotundus* to flooding maybe attributed to large carbohydrate content and amylase activity, and the ability to maintain high levels of soluble sugars in the tubers during germination and early growth.

Majority of the *Cyperus species* are classified as perennial plants while very few are annuals allowing them to establish biological and reproductive advantages over other plants. The Cyperaceae is a highly competitive weed capable of persisting in varied and intense terrestrial environment (drought, high light, high temperature) Hopkins & Huner, (2004).

ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
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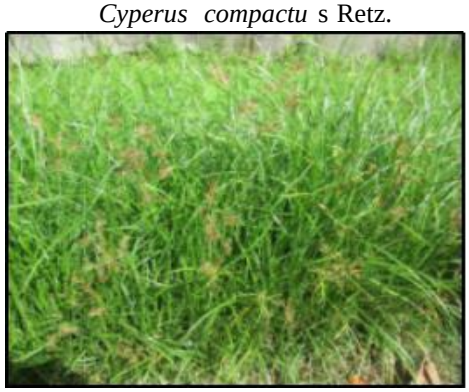
In Nueva Ecija, Donayre et al., (2015) mentioned that 26 villages in the province showed high infestations of *Cyperus rotundus* in areas with low elevations. The same species was found to be the dominant weed in upland rice areas, a minor problem in rain fed lowland and the second most dominant weed in rain fed and irrigated lowland ricefields in rice-vegetable system in San Jose City, Nueva Ecija. However, Detalla & Sinamban (2008) recorded a low infestation for *Cyperus brevifolius*, *Cyperus iri*a, *Cyperus javanicus* and *Fimbristylis miliacea* in the 5 municipalities of Bukidnon representing the Southern, Central and Northern Mindanao and 12 barangays.

This paper was not able to establish quantitatively the negative effects of sedges on the economy but show us the imminent risk to our agricultural system because of the existence of the sedge species known to be the world's worst weeds as well as the environmental conditions of the country that is highly adaptable to their growth.

The bioinvasion tool was accomplished by the researcher based on her actual observation of the study areas. Results show that *Cyperus compactus* , *Cyperus imbricatus, Cyperus rotundus* and *Cyperus esculentus* are found highly invasive in Masbate (Table 3, Figure 1). This was supported by Holm et al., 1977, Simpson, 2011) when they reported that *Cyperus rotundus, Cyperus esculentus* and *Fimbristylis milliaceae* as highly invasive species in other countries. On the other hand, *Fimbristylis milliaceae* known to be worst weed in other countries were found slightly invasive in the identified study areas.

Cyperus compactu s Retz.

Cyperus imbricatus Retz.



***Cyperus rotundus* L.**

***Cyperus esculentus* L.**

Figure 1 . Highly Invasive *Cyperus species* in Philippines

Table 4. Noxious Weed Qualitative Assessment of Cyperus species in the Philippines (Modified ODA Tool, 2010)

CATEGORY	SUB-CATEGORIES		PROVINCES			Ave. Weighted Mean
I.GEOGRAPHICAL INFORMATION		MASBATE	TARLAC	NUEVA VISCAYA	ISABELA	
	Invasive In Other Areas	5.08	4.12	4.89	5.77	4.97
	Habitat Availability	4.77	3.47	5.33	5.08	4.66
	Proximity To Your Place	4.23	2.0	4.78	3.08	3.52
	Current Distribution	7.46	1.76	5.78	4.69	4.92

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II. BIOLOGICAL INFORMATION						
	Environmental Factors	3.62	2.71	3.81	4.0	3.53
	Reproductive Traits	5.0	3.29	5.70	5.77	4.94
	Biological Factors	4.0	3.0	3.0	4.0	3.5
	Non-Human Factors	4.38	2.53	2.33	2.23	2.87
	Potential To Be Spread By Humans	3.77	2.06	4.41	3.0	3.31
III.IMPACT INFORMATION						
	Economic Impact	7.38	3.88	4.59	4.15	5.0
	Environmental Impact	4.69	2.06	1.26	1.85	2.465
	Impact On Health	3.69	1.41	.37	.15	1.405
IV.CONTROL INFORMATION						
	Probability Of Detection At Point Of Introduction	8.08	2.88	5.85	3.77	5.145
	Control Efficacy	5.46	2.82	3.89	4.15	4.08
SUM		60.46	34.82	50.84	45.85	47.99
INTERPRETATION		**A**	**B**	**B**	**B**	**B**

Results shows *Cyperus rotundus* (Purple nutsedge) as a Noxious weed (A) when evaluated using the ODA tool(Table 4). This can be due to the fact that it has developed modifications in structure for survival and climate change(Rogers et al. 2008, GISD,2015, Scherr &McNeely,2008). A lowland ecotype was found inhabiting lowland and irrigated ricefields in the country (Donayre et al. 2016, Peña-Frontreras et al.,2009). Actual field observation and interview showed that many farmers have limited knowledge about the identity of the weeds in their farm and some problems on cultural practices.

A. FARMERS PROFILE:

A total of one thousand four hundred fifty seven farmers from the identified municipalities in the Provinces of Masbate (359); Tarlac (371), Nueva Viscaya (369) and Isabela (358) had taken part in the actual survey. Results shows (Figure 2) the farmers profile in the identified study sites. This would tell us that farming in the Philippines is a gender related activity though male controlled the population this can be attributed to the strenuous activities associated with it.

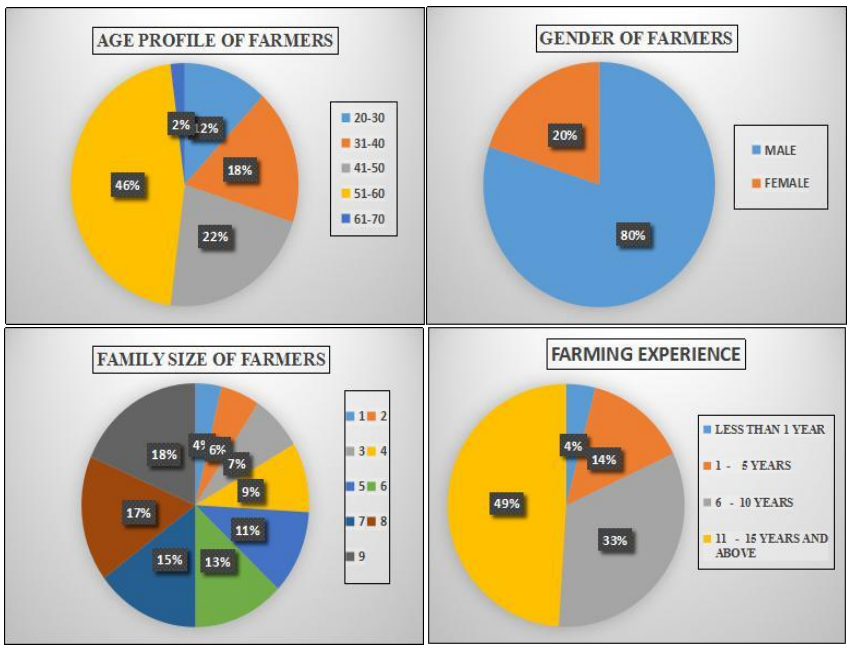

Figure 2. Gender, Age Profile and Family size of the Farmers of Masbate, Tarlac, Nueva Viscaya And Isabela

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Forty six percent (46) of the farmers are experienced and of age (51-60); 22 % (41-50) years old and 49% have been farming for 11 to 15 years or more thus, the relative incidence of *Cyperus species* in their farms are well observed. A few (12%) is composed of young generation aged 20-30.

B. THE AGRICULTURAL SYSTEM AND ITS CONDITION:

Family size of farmers vary from 3, 5, 6, 7 8 offsprings. Majority of these farmers depend solely in farming for their source of income (91%) while the remaining 9% have other sources (LGU salary, business, etc.).(Figure 3). Hence, problems associated with weeds brought about by *Cyperus species* and other grasses can greatly affect their living conditions.

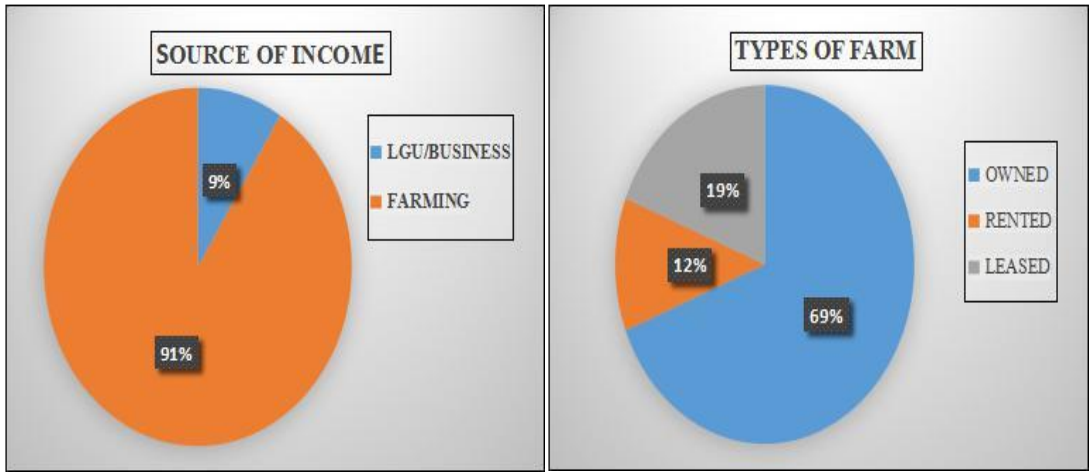

Figure 3. Farmers Source of Income and Types of Farm

Sixty nine percent(69%) of the farmer respondents have their own land while others are rented and leased. Majority of the farmers from Masbate, Tarlac, Nueva Viscaya and Isabela are rice and corn growers(Figure 4).

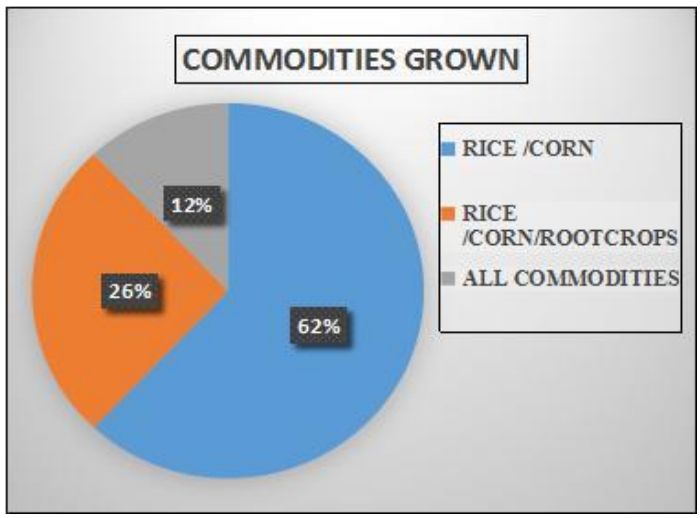

Figure 4 Source of Income and Types of Farm

However, in Isabela and Nueva Viscaya some of the farmers are only vegetable growers. Weed infestation is one of the main problem of the farmers in the study sites specifically on grasses and sedges. Forty seven percent of the farmers were able to identify 4-6 types of sedges in their farms while 45% have observed 1 to 3 species only. A frequency of one to twenty Cyperus plants per paddy were documented by 48 % of the farmers in their farms. Many farmers (62%) consider the presence of *Cyperus species* and grasses in their ricefields as costly due to their dependence to weedicide as a control measure. The identified problematic sedges includes: *Cyperus esculentus* L.; *Cyperus rotundus* L.; *Cyperus iria* L.; *Cyperus difformis* L. In some places *Cyperus distans* , *Cyperus imbricatus*, *Cyperus compactus* , *Fimbristylis miliacea* dominated their farms. It was also observed by many farmers that water and wind (49%) as the leading manner of dispersion(Figure 5).

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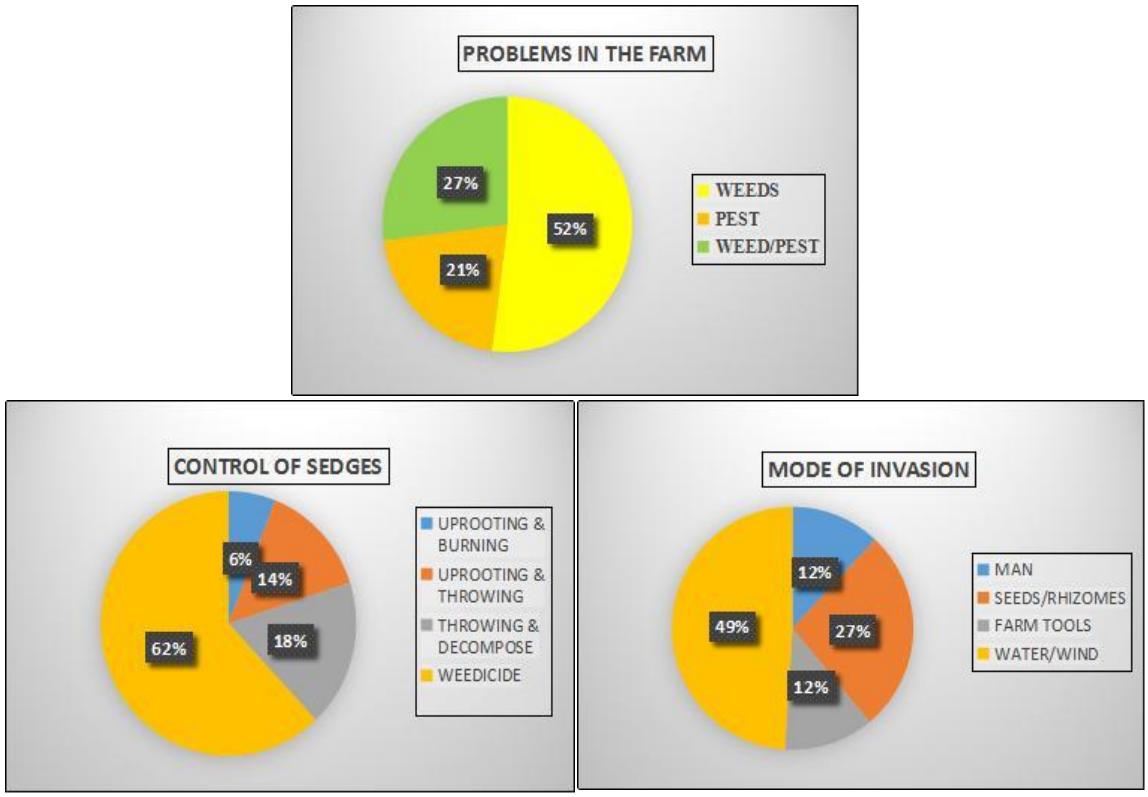

Figure 5. Control of Sedges and Mode of Invasion

Moreover, 50% of the farmers observed that the presence of *Cyperus* weed species can led to surrounding crops become unhealthy. Best soil types for their growth ranges from sandy, loamy to clayey and well adapted to wet to moist habitat. Sunny condition (59%) is critical to the growth and development of sedges as cited in previous studies.

Many of the farmers do not have complete knowledge of the weeds that thrive in their ricefields while 70 % consider Cyperus species as feeds to animals, 10% do not have any idea of their benefits while others use it as medicine to animals and some of ornamental uses. Some farmers consider 1 to 4 weeks time period to maturity as best condition for consumption by grazing animals due to its herbaceous conditions and soft at younger stage.

Sixty percent of the farmers consider seeds and rhizomes as the *Cyperus species* mode of reproduction. Cyperus invasion is considered a threat to the farm due to possible pest and diseases associated with it.

However, Cyperus species were found to grow well with seeds and potentially regrows in vegetative growth.

Almost 62% of the farmers considered *Cyperus species* as difficult to control and 19% considered control is costly, 8. 9% as no effective control while 9.26% as recurrent. Thus, *Cyperus species* infestation is very observable in many areas in the country.

III. CONCLUSION

This study appeared to support previous studies conducted by other authors, however, some new informations are evident.

1. Fourteen *Cyperus spe*cies were found inhabiting the ricefields of Masbate, Tarlac, Nueva Viscaya and Isabela. The species *Cyperus rotundus*, *Cyperus iria*, *Cyperus difformis* and *Fimbristylis miliacea* were previously identified as world's worst weeds in 95 countries. These species are among the species found in the Philippines. However, several species are found also to be highly invasive in some provinces as in the case of *Cyperus esculentus*, *Cyperus compactus* , *Cyperus distan*s and *Cyperus imbricatus* together with *Cyperus rotundus*.

2. Twenty -eight point fifty-seven percent (28.57%) or 4 out of 14 are considered Highly Invasive, 7 out of 14 or (50%) as Slightly Invasive and three out of fourteen (21.43%) or 3 out of 14 as Not Invasive .

3. Both the bioinvasion analysis and Qualitative weed Assessment Tool established the categories of *Cyperus species*. Masbate was able to identify many invasive species and categorized some species as noxious weeds.

This study has established that the agriculture system is a gender related activity in the Philippines. Though, majority of the farms are managed and maintained by male farmers this can be due to the strenuous activities associated with it.

A similar study is highly recommended in order to create a GIS data base of the risk prone areas for Cyperus infestation .

A future action policy be formulated in relation to the control of the movement of *Cyperus rotundus* lowland ecotype in areas where the species are not observed. This is aimed to limit its distribution.

ACKNOWLEDGEMENT

The researcher wish to acknowledge the financial support extended by the Commission on Higher Education, the technical assistance granted by the delivering institution, the University of San Carlos and the sending institution, the Dr. Emilio B. Espinosa, Sr. Memorial State College of Agriculture and Technology.

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