Original Article: Management of weeds in irrigated rice cultivation in the middle valley of the Senegal River

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ABSTRACT

In the valley of the Senegal River, weeds represent one of the major constraints of irrigated rice cultivation. In that context, the development of efficient and adapted methods for better management of weeds is critical. This study aims at evaluating the efficacy of the combination of two formulations of herbicides (Eros Gold and Londax) and two sowing methods (direct sowing and transplanting) on rice weeds in a Split Plot design with three replicates. The weed flora was evaluated through phytosociological surveys with three observations: before heading, after heading and ripening stages of rice. Floristic surveys identified 16 families, 25 genera and 28 species of weeds. In addition, the results showed that Eros Gold had a significant effect with sowing methods on the decrease of sedges and grasses density but more specifically on the abundance-dominance of broadleaf weeds (dicotyledons) before and during heading stages of rice. On family groups, Cyperaceae (15.39 ind/ha), grasses (15.72 ind/ha) and dicotyledons (24.94 ind/ha) are more sensitive to Eros Gold in broadcast sowing than in transplanting mode with 26, 56 ind/ha, 26.50ind / ha and 27.94 ind/ha respectively.

Introduction

Rice (*Oryza* sp.) is a cereal with great importance in the world. It is the second most cultivated cereal, and the third most consumed and exported in the world (FAO, 2013). Senegal is the second-largest importer of rice in West Africa after Nigeria (MAH, 2004). These imports continue to create a disequilibrium in the trade balance of the country with currency outflow of about 100 billion CFA per year (Gueye, 2004). To mitigate these adverse effects on the economy, the State took the option of developing irrigated rice cultivation in the regions of Saint-Louis and Kolda and the consolidation of rainfed rice cultivation in the south (Ndione, 2010). In 2014, Senegal made self-sufficiency in rice a priority through PRACAS (program to accelerate the pace of agriculture in Senegal) (MAER, 2014). However, biotic and abiotic constraints constitute the actual brake of rice production. Among these biotic constraints, weeds constitute a crucial problem, and their control is a fundamental element for the enhancement of production factors (Rodenburg and Johnson, 2009). Uncontrolled evolution of weeds can lead to a total loss of rice production, although such

circumstances are exceptional (Johnson, 1997). In Africa, these losses are estimated at 2.2 million tons per year for an estimated cost of 700 billion CFA francs (Rodenburg and Johnson, 2009; Le Bourgeois et al. 2014; Ayodele and Olubunmi, 2017). Therefore, weed management constitutes a significant concern of Senegalese farmers (Noba, 2002; Mbaye, 2013). However, to design the weeds control strategy, it is imperative to characterize the weed flora and understand its chemical, physical, mechanical, and manual strategies management. In lowland and rainfed rice production systems at Casamance (southern Sénégal), herbicides are a profitable investment low fertility soils (Posner and Crawford, 1991). However, in the valley of the Senegal river, the resistance of certain weeds to herbicides is still increasing (Mballo, 2019). Thus the choice of the variety of rice and the method of sowing is a way to make the crop more competitive against weeds (Saito et al. 2010; Rodenburg and Johnson, 2009; Rodenburg et al. 2011). Boraud et al. (2015) found that in rice cultivation in central Côte d'Ivoire, obtained the best yield with only chemical weed killers. The use of chemical weed killers has grown in all parts of Africa (Ipou Ipou et al. 2016) and has become an important alternative to agricultural labor. However, chemical control has limits because of the resistance phenomena observed (Johnson, 1997; Lopes Ovejero et al. 2013) and can have consequences on human health (sterility, cancer, etc.) and the environment (Konan et al. 2014; Kouadio et al. 2014). Faced with these shortcomings in the management of grass cover, it is therefore necessary to offer rice growers alternative control methods, combining in particular less harmful chemical weed control and the sowing method for a better efficiency of the fight against weeds of rice. This study aims at contributing to the management of weeds in irrigated rice cultivation in the valley of the Senegal river for sustainable rice production. The specific objective of the study was to assess the combined effect of Eros Gold and Londax herbicides and sowing methods on rice weeds in ISRA agricultural research station at Fanaye.

Materials and Methods

Location of the study site

The study was conducted at the experimental station of Fanaye (16°33 North and 15°46 West, Department of Podor) in the agro-ecological zone of Middle Valley. It is located at about 160 km North-East of Saint-Louis and 410 km from Dakar. The station covers an area of 40 ha from which only 17 ha is used and located on the right bank of an arm of Senegal river. It is an excellent rice-growing area that host all the rice varietal selection experiments and herbicide efficacy trials on rice weeds. The soils of the site are hydromorphic to gleys or pseudogleys. They are heavy soils with clay content greater than 30%, locally called "Faut Hollaldé". The climate is Sahelian with a short rainy season of 2 to 3 months (July-September) and a dry season spanning 9 to 10 months (October-June). Temperatures are relatively high throughout the year with maximum temperatures varying between 31.6 °C and 42 °C and a minimum of 15.7 °C to 25.5 °C. The average annual rainfall is around 220 mm (ANACIM, 2017).

Plant Material

SAHEL 108, a variety of irrigated rice approved in Senegal was used. It is a variety of *Oryza sativa*, in the group of Indica varietal with a cycle of 105 days in overwintering and 117 days in the hot, dry season. It is characterized by a potential yield of up to 10 t ha^{-1} (ISRA, 2012).

Herbicides

The herbicides used for the study were Eros gold and Londax. Eros Gold is a new formulation in soluble granules of Pyrazosulfuron 0.75% + pretillachor 30%. It works by inhibiting the synthesis of acetolactate (also known as acetohydroxyacid), blocking the biosynthesis of branched-chain amino acids of valine, leucine and isoleucine and thus cell division and fatty acid production. This inhibition leads to immediate arrest of weed growth. Londax or Bensulfuron methyl or benzoacid is a non-selective systemic herbicide with an active ingredient Pyrimidinyl sulfonylurea. Absorbed by the foliage and the roots, it has a rapid action on the meristematic tissues and controls in rice fields the annual broadleaf weeds.

Experimental design

The study was set up according to a split-plot experimental design with two factors (Herbicides and sowing methods) and three replicates. Londax and Eros Gold herbicides (primary factor) were applied to direct sowing and transplanting (secondary factor). Three (3) blocks of 60 m^2 were established. Each block was subdivided into six (6) elementary plots of 15 m^2. The elementary plots were separated in the block with dyke of 50 cm. 1m irrigation canals separated the blocks.

Experimental setup

Treatments based on Eros Gold and Londax 60 DF were applied at early post-emergence stage (2-4 leaves stage) of weeds. For each herbicide, the recommended dose was applied (1.75 kg/ha for Eros Gold and 80 g / ha for Londax 60 DF). For the control plots, no herbicide was applied (untreated plot or T0).

A basal fertilizer with organic matter and DAP (NP0) was applied before plants emergence or transplanting to ensure good germination of direct sowing and resumption of transplanted rice plants. NPK 10-10-20 fertilizer and urea were applied every 21 days at the doses of 90 kg/ha and 300 kg/ha, respectively. Broadcast sowing was carried out with pre-germinated grains at a density of 120 kg/ha. Regarding the transplanting method, the plants were grown in a nursery for a month before being transplanted with 15×10cm^2 of crop geometry. Plants were irrigated twice a week with a water slide of 5 cm during the vegetative phase and 10 cm during the reproductive phase while respecting the drainage as needed.

Measurements of Phytosociological parameters of weeds

Inventory of weed flora

The floristic survey technique used was a field survey, which allows to inventory the species of the plot exhaustively (Maillet, 1981; Le Bourgeois, 1993). For each survey, the species present were recorded by family group (Grasses, Sedges, Dicotyledons) and abundance-dominance scores were assigned according to Braun-Blanquet (1952) scale. Three inventories were carried out: before rice heading stage (early seedling stages of weeds), at rice heading stage (adult plant stages of weeds) and the rice maturation period (senescent weed plant stages).

Identification of species encountered

Most of the species encountered were identified in the field. However, unidentified plants were sampled and sent to Dakar Herbarium for identification. Species were identified using the floras (Berhaut, 1967, 1971; Le Bourgeois and Merlier, 1995; Akobundu and Agyakwa, 1989; Johnson, 1997). The nomenclature used is that of Lebrun and Stork (1991-1997). For biological types, we used the classification of Lebrun, (1966), Raunkier (1934). This classification distinguishes 6 biological forms which are: nanophanerophytes (P), chamephytes (C), hemicryptophytes (H), geophytes (G), therophytes (T), and parasitic plants (Par). For the geographical distribution, the information came mainly from the flora of Hutchinson and Dalziel (1972) and Traore and Maillet (1992).

Statistical analysis

R software was used for the analysis of variance of the parameters measured, and the means were separated using the Student-Newman-Keuls test. From the plots surveyed, the following elements were calculated: Centesimal frequency (FC) or distribution of a species in the population represents the percentage of plots surveyed where the species was found (Godron, 1968); Average abundance/dominance index (ADm), calculated in relation to the number of plots surveyed in which the species was present (Le Bourgeois, 1993). The abundance/dominance indices were matched in the class of cover and average cover (Table 1). PCA was performed to determine the distribution and specific composition of species at the elementary plot level.

Table 1. Transformation of Abundance-Dominance into average percentage recovery (Gounot, 1969).

Abundance–dominance Indice	Recovery class	Average recovery (%)
5	75-100	87,5
4	50-75	67,5
3	25-50	37,5
2	10-25	17,5
1	1-10	5,5
+	0-1	0,5

Results and Discussion

Specific composition of weeds flora

Table 2 presented the list of weeds species inventoried in the station of Fanaye. Twenty-eight (28) species distributed in 25 genera belonging to 16 families were identified in this study. The Poaceae (8 species), Cyperaceae (3 species), Malvaceae (3 species) and Asteraceae (2 species) families were the most common. All other recorded families were represented by one species only.

Effect of treatments on the density of weed populations per family groups

Variation of the density of weed populations of different family groups according to the observation periods

Density evolution of Cyperaceae, also known as sedges, Poaceae (grasses) and dicotyledon families depending on the observation periods, is presented in Table 3. There was no significant difference between the observation periods for the density of grasses and sedges. However, a significant difference was noted between the observation periods in dicotyledons. The density of dicotyledons was lower before and at heading stages as compared to the maturity period of rice.

Average density variation of weed populations of different family groups according to the treatments

For each family group (sedges, grasses and dicotyledons), the analysis of variance (Table 4) indicated a significant difference between weed densities in the different treatments. The sedges were less abundant in broadcast sowing plots treated with Eros Gold (15.39 individuals / 0.25m²). Eros Gold effectively controlled weed grasses in broadcast sowing plots with an average density of 15.72 individuals / 0.25 m². Londax was most effective to control grasses in transplanted plots. For dicotyledons, transplanted plots treated with Londax presented the lowest grass cover (18.22 individuals/0.25m²) as compared to other treatments.

Distribution of weed species according to the observation periods and treatments

Distribution of weed species before rice heading stage (early stage of weeds)

The distribution of variances of weed species before heading stage of rice is presented in Table 5. The percentage of cumulative information on the two (2) axes was 95.59%. The horizontal axis, which explained 86.48% of the information, allowed to discern the efficacy of the different treatments (sowing methods and herbicides) on weed species and the vertical axis (9.11%) showed the resistance of certain species according to the treatments.

Table 2. List of inventoried weed species with the number of families and genera.

Families	Genera	Number of species	Species
Amaranthaceae (D)	1	1	*Alternanthera sessilis* (L.) R. Br. ex DC.
Asteraceae (D)	2	2	*Eclipta alba* (L.) Hassk *Blumea aurita* (L. f.) DC.
Boraginaceae (D)	1	1	*Heliotropium indicum* L.
Convolvulaceae (D)	1	1	*Ipomoea acanthocarpa* (Ch.) Asch. & Sch.
Cyperaceae (M)	2	3	*Cyperus iria* L. *Cyperus difformis* L. *Fimbristylis littoralis* Gandich
Elatinaceae (D)	1	1	*Bergia suffruticosa* (Delile) Fenzl
Euphorbiaceae (D)	1	1	*Euphorbia hirta* L.
Fabaceae (D)	1	1	*Aeschynomene indica* L.
Haloragaceae (D)	1	1	*Laurembergia tetrandra* Auct.
Lythracées (D)	1	1	*Ammannia auriculata* Willd.
Malvaceae (D)	2	3	*Corchorus fascicularis* Lam. *Corchorus olitorius* L. *Sida alba* L.
Onagraceae (D)	1	1	*Ludwigia abyssinica* A. Rich.
Phyllanthaceae (D)	1	1	*Phyllanthus amarus* Schum. & Thon.
Plantaginaceae (D)	1	1	*Scoparia dulcis* L.
Poaceae (M)	7	8	*Dinebra retroflexa* (Vahl) Panz.p) *Echinochloa colona* (L.) Link *Eragrostis japonica* (Thunb.) Trin. *Eragrostis cilianensis* (All.) F.T.Hubb. *Oryza barthii* A. Chev. *Panicum laetum* Kunth *Digitaria horizontalis* Willd *Paspalum scrobiculatum* L.
Portulacaceae (D)	1	1	*Portulaca oleracea* L.

M: Monocotyledons; D: Dicotyledons

Table 3. Evolution of density of different family groups of weeds according to the observation periods.

Rice plant stages	Rank (Sedges)	Rank (Grasses)	Rank (Dicotyledons)
Before heading	27,83±12,01a	23,22±17,69a	20,03±12,60b
At heading	23,22±17,84a	25,50±14,72a	25,19±13,92b
At ripening	31,44±15,93a	33,78±12,52a	37,28±14,00a
P-value	1,5568	2,9124	11,4884
Pr(>F)	0,22466	0,06724	13,84.10e-5***

Figure 1 presents the distribution of weed species based on the abundance and dominance in the plots according to the different treatments before rice heading stage using Principal Component Analysis (PCA). Analysis of Figure 1 showed that some species: (*C. iria* and *E. colona*) were resistant to the two herbicides used. Therefore, they were abundant in either treated or untreated plots. However, *E. colona* resisted only in direct sowing plots treated with Londax and *C. iria* in plots treated with Eros Gold. On the other hand, *D. retroflexa*, *A. auriculata*, *L tetranda*, *P. amarus*, *A. indica*, *F. litoralis*, *C. olitorius*, *P. laetum*, *E. cilianensis*, and *D. horizontalis* seemed to be sensitive to the herbicides regardless of the sowing methods. At the seedling stage, *C. iria* was better controlled with Londax while Eros Gold controlled *E. colona*. All other species encountered were well controlled by both herbicides.

Table 4. Average density evolution of weed populations of different family groups according to the treatments.

Sowing methods		Rank (Sedges)	Rank (Grasses)	Rank (Dicotyledons)
Transplanted	RL	26,50±12,68abc	23,67±18,81ab	18,22±17,47a
	RE	26,56±13,82abc	26,50±12,82ab	27,94±08,89b
	RSH	41,17±11,55a	36,39± 13,61a	43,22±13,01b
Broadcast	VL	18,94±9,28bc	26,94±11,66ab	20,56±11 ,93b
	VE	15,39±1368c	15,72±16,28b	24,94±11,46b
	VSH	36,40±17,04ab	35,78±16,28a	30,11±12,50b
P-Value		4,548	3,4368	7,3757
Pr (>F)		4,47.10e-4**	0,0177*	19,06.10^{e-5} ***

RL: Transplanted Londax; RE: Transplanted Eros Gold; RSH: Transplanted without herbicides; VL: Broadcast Londax; VE: Broadcast Eros Gold; VSH: Broadcast without herbicides.

Table 5. Distribution of variances of weed species before rice heading stage

	Axis1	Axis2	Axis3	Axis4	Axis5
Variances	5,19	0,55	0,17	0,09	0,01
% variances	86,48	9,11	2,83	1,45	0,10
% Cum, Variances	86,48	95,59	98,42	99,88	99,98

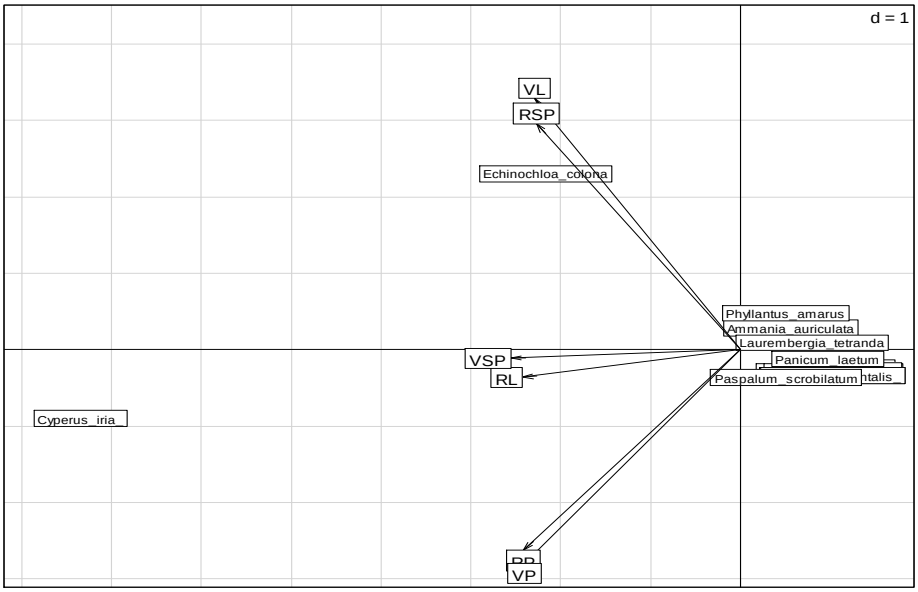

Figure 1. Distribution of weed species in the different treatment plots before heading stage of rice.

Distribution of weed species at the rice heading stage (adult stage of weeds)

Table 6 shows the distribution of variances of weed species at rice heading stage. The first two axes represented 74.5% of the information of the total inertia of variance. The vertical axis represented about 48.97% of the information. It showed that Londax effect as opposed to those of Eros Gold and the horizontal axis representing 25.54% of the information allowed to isolate the weed species that were sensitive to herbicides from those which were resistant.

Table 6. Distribution of variances of weed species at rice heading stage.

	Axis1	Axis2	Axis3	Axis4	Axis5
Variances	2,94	1,53	0,88	0,43	0,17
% variances	48,97	25,54	14,68	7,10	2,78
% Cum, Variances	48,97	74,50	89,19	96,29	99,07

The degree of infestation of weed species in the different elementary plots during the heading of rice is presented in Figure 2. Analysis of this figure showed that: *C. difformis*, *C. iria*, *S. alba*, *E. japonica* and *C. olitorius* were the resistant species to both herbicides at adulthood. However, *C difformis* was more resistant to Eros Gold, *E. japonica* resistant to Londax. At the same time, *C. iria*, *S. alba* and *C. olitorius* had the same trend of resistance to both herbicides. Resistance at the maturity of the species seemed to be regardless of sowing methods. Also, Eros Gold and Londax effectively controlled the rest of the weed species at adulthood: *E. colona*, *D. retroflexa*, *A. auriculata*, *L. tetranda*, *P. amarus*, *A. indica*, *F. litoralis*, *P. laetum*, *E. alba*, *E. hirta*, *P. oleracea*, *O. barthii*, *I. acanthocarpa*, *B. aurita* and *C. fasicularis*. It is also observed that *C. iria* and *E. colona*, which were resistant at the young plant state, became susceptible to the herbicides at adulthood.

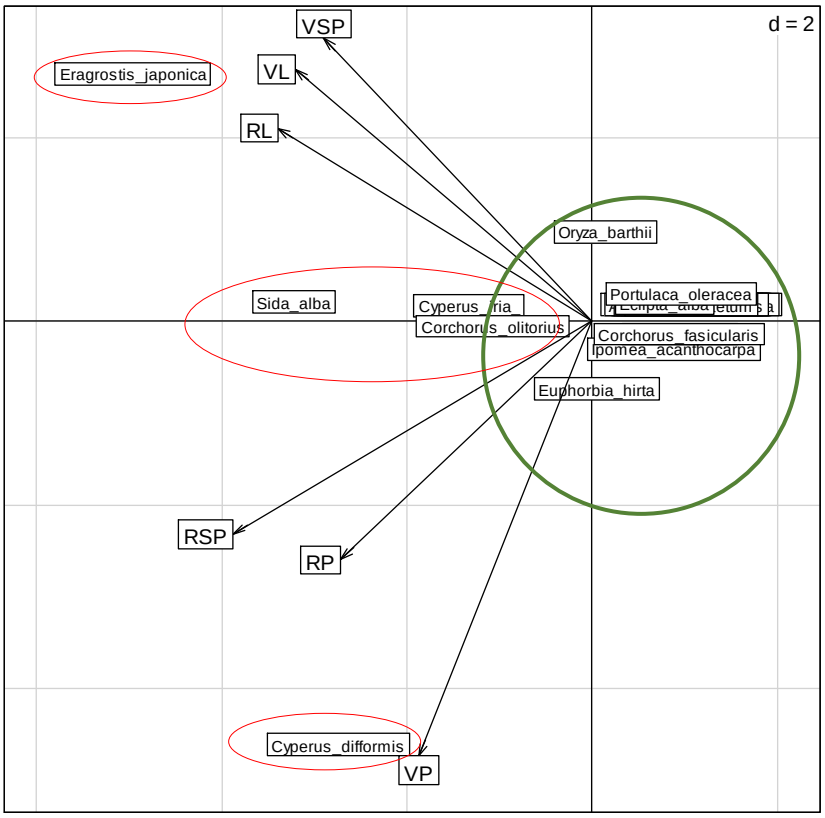

Figure 2. Distribution of weed species in elementary plots of different treatments during the heading stage of rice.

Distribution of weed species during rice ripening (senescent stage of weeds)

Table 7 shows the distribution of variances of weed species at maturity phase of rice. The two axes are chosen together represented 68.86% of the total inertia information of variance. The horizontal axis alone represented 44.67% of the information. This axis allowed to isolate species resistant to the herbicides. The vertical axis representing 24.19% of information and indicated the effectiveness of herbicides.

Table 7. Distribution of variances of weed species at maturity phase of rice

	Axe1	Axe2	Axe3	Axe4	Axe5
Variances	2,68	1,45	1,12	0,54	0,17
% variances	44,67	24,19	18,71	8,94	2,89
% Cum, Variances	44,67	68,86	87,57	96,50	99,39

Analysis of Figure 3 indicated that all of the following species were more abundant in plots treated with Eros Gold and control plots regardless of the sowing methods: *E. colona*, *D. retroflexa*, *L. tetranda*, *P. amarus*, *A. indica*, *F. litoralis*, *C. olitorius*, *P. laetum*, *S. alba*, *E. albonia*, *E. japa*, *E. japan*, *P. oleracea*, *O. barthii*, *I. acanthocarpa*, *B. aurita*, *C. fasicularis*, *L. abyssinica*, *B. sufriticosa*, *S. dulcis*, *H. indicum*, *A. sessilis*.

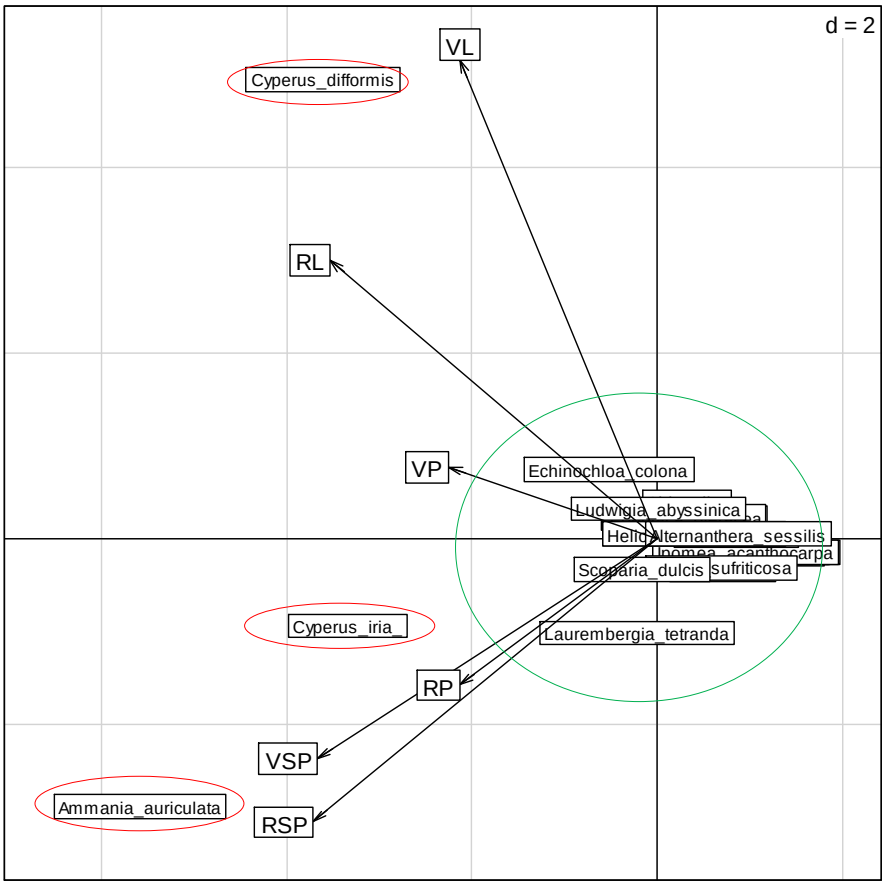

Figure 3. Distribution of weed species in elementary plots of different treatments during rice ripening.

The number of taxa encountered in this study appears to be low as compared to those of the weed flora of irrigated rice fields of the valley of Senegal River. The total number of species recorded in all phytosociological surveys was 90, distributed in 27 families. The weed flora of irrigated rice fields of Daloa at central-western of Côte d'Ivoire revealed a total of 148 species belonging to 102 genera distributed in 40 families (Sylla et al. 2017). The differences of results in the valley of Senegal River could be due to the fact that the study was carried out in a much larger number of plots (127 plots) or larger surface area of plots as compared to those in Daloa with an area of 110.25 m² per elementary plot (10.5 m x 10.5 m). On the other hand, the differences were considerable as compared to those of Boraud et al. (2015) in rice cultivation at the center of Ivory Coast where 16 species were identified, distributed in 14 genera and belonged to 10 families. The results showed that the transplanted and direct sowing plots treated with Londax had the lowest grass cover of dicotyledons (18.89 individuals/0.25m²) and (20.56

individuals/0.25m²), respectively as compared to those treated with Eros Gold. Therefore, Londax controls dicotyledons effectively in transplanted rice plots as well as in broadcast sowing plots. In untreated plots, either transplanted or broadcast sowing had the highest level of weeds. The use of herbicides after weed emergence is more effective when the weeds are still at the seedling stage (Johnson, 1997). In contrary, *C. iria* and *E. colona* were resistant to Eros Gold and Londax herbicides at that stage. These results corroborate with those obtained by Botella (2005), which states that the genus Echinochloa seems according to some producers no longer to be controlled by certain herbicides on the market. Furthermore, laboratory tests have confirmed cases of resistance of *E. colona* and *E. obtusiflora* to sulfonylurea products.

Transplanting rice plants gives a considerable advantage for weed germination over direct sowing. Weeds are less voracious in direct sowing systems than in transplanting (Johnson, 1997). The two herbicides used, namely Eros Gold and Londax, are based on pretilacolor and bensulfuron, respectively. And according to (Johnson, 1997), sedges are sensitive to herbicides based on these active ingredients. Thus, herbicides (Eros Gold and Londax) effectively control the majority of species in the adult state: *E. colona*, *D. retroflexa*, *A. auriculata*, *L. tetranda*, *P. amarus*, *A. indica*, *F. litoralis*, *P. laetum*, *E. alba*, *E. hirta*, *P. oleracea*, *O. barthii*, *C. iria*, *I. acanthocarispa*. Even *C. iria* and *E. colona*, which were resistant as a young plant, became fully susceptible to herbicides at adulthood. Therefore, at maturity, the degree of leaf absorption increases with the increase in leaf area. Grard et al. (2012) showed that Londax effective against perennial broadleaf weeds. However, Eros Gold effectively controls weed grasses in broadcast plots with an average density of 15.72 individuals / 0.25 m². Londax is more effective in transplanted plots. The transplanted and broadcast control plots have the highest level of grass cover. Rahman et al. 2014 have shown that some residual herbicides used for weed control in corn crops can sometimes persist in the soil. Which negatively affects crop rotation (Mehdizadeh, 2019).

Conclusion

This study evaluated the effectiveness of two herbicides Eros Gold and Londax according to two sowing methods, namely broadcast sowing and transplanting. The efficacy of Eros Gold for weed control is generally more effective on sedge and grass families, while Londax is more effective on broadleaf weeds. The effectiveness of both herbicides appears to be more pronounced with broadcast sowing. The species *E. colona* and *C. iria* appear to be resistant to both herbicides.

Conflicts of Interest

The authors have declared no conflicts of interest.

References

Akobundu O.I, Agyakwa C.W. 1989. Guide to West African weeds. Ibadan (Nigeria): IITA, 522p. **[Publisher]**

Aminou S. 2016. List of herbicides for sale in Niger, National Network of Chambers of Agriculture of Niger, 9p**. [Publisher]**

Ayodele O, Olubunmi A. 2017. Weed Management Strategies for Conservation Agriculture and Environmental Sustainability in Nigeria. *IOSR J Agric Veter Sci*. 10(8): 1-8. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Berhaut J. 1967. Flora of Senegal. 2nd Ed. Dakar, Clairafrique. 485p. **[Publisher]**

Berhaut J. (1971). Illustrated flora of Senegal. Volume I, II, III, IV, V and VI. Government of Senegal, Dakar. **[Publisher]**

Boraud N.K.M, Kouame K.F, Kla D. 2015. Impact of weed management practices on rice yield in central Côte d'Ivoire. *Int J Biol Chem Sci*. 9 (3): 1220-1228. **[Google scholar]**, **[Publisher]**

Botella J. 2005. Assessment of the risk of emergence of resistance to herbicides in rice weeds in the Camargue. ENITAB. **[Google scholar]**

Braun-Blanquet J. 1952. Applied phytosociology. *SIGMAT*. 116: 157-161. **[Google scholar]**

FAO. Rice Market Monitor. 2013. Trade and Markets Division Food and Agriculture Organization of the United Nations. FAO. **[Google scholar]**, **[Publisher]**

Gueye A.A. 2004. Bibliographic study on the rice sector in Senegal, final report of the regional workshop of the Project to Strengthen Information for Rice Sector Actors in terms of markets and policies (PRIAF-RIZ) Bamako, May 10 to 14, 71p. **[Google scholar]**

Godron M. 1968. Some applications of the concept of frequency in plant ecology. *Oecol Plant.* 3: 185-212. **[Google scholar]**

Gounot M. 1969. Methods for the quantitative study of vegetation. Ed. Masson et Cie, Paris, France, 314p. **[Google scholar]**

Grard P, Bourgeois L.E, Rodenburg T, Marnotte J, Carrara P, Irakiza A, Makokha R, Kyalo D, Aloys G, Iswaria K, Nguyen K, Tzelepoglou G. 2012. Weed management in lowland rice systems in Africa. *AFRO weeds*. 1: 1-15. **[Google scholar]**

Hutchinson J, Dalziel J.M. 1972. Flora of West Tropical Africa 2nd ed. CAOGA Publications, London. **[Crossref]**, **[Google scholar]**, **[Publisher]**

ISRA 2012. Upland rice production guide, 36p.ISRA (2012b) - Official catalog of species and varieties cultivated in Senegal. **[Google scholar]**

Ipou Ipou J, Mahamane A, Yapi A.F. 2016. Chemical weed control of crops in Ivory Coast: socio-economic and agricultural issues. AFPP-23rd COLUMA conference, international days on weed control, Dijon-6, 7 and 8 December 2016. **[Google scholar]**

Johnson D.E. 1997. Weeds in rice cultivation in West Africa. Ed. WARDA / WARDA. 312 p. **[Google scholar]**

Konan Y, Akanvou L, N'Cho S, Arouna A, Eddy B, Kouakou C.K. 2014. Analysis of the technical efficiency of rice farmers in the face of infestation of crops by Striga parasitic species in Côte d'Ivoir. *Rev Ivoir Sci Technol*. 23: 212-223. **[Google scholar]**

Kouadio Y.P, Tiébré M.S, Kouassi R.H, Kassi N.J, N'Guessan K.E. 2014. Limits of chemical weed control in industrial banana plantations in Dabou in the south of Côte D'ivoire. American Journal of Scientific Research, ISSN 2301-2005 Issue 101 April, 2014, pp. 64-74. **[Google scholar]**

Le Bourgeois T, Grard P, Marnotte P, Rodenburg J. 2014. Improving the management of grass cover in rice fields in Africa by sharing information and helping to identify weeds: the potential of the AFROWeeds collaborative platform. htpp: //www.africarice.org, accessed December 12, 2015. **[Google scholar]**

Le Bourgeois T, Merlier H. 1995. Adventrop : weeds from Sudano-Sahelian Africa. Montpellier: CIRAD - CA 637 p. **[Google scholar]**

Le Bourgeois T. 1993. Weeds in the cotton rotation in North Cameroon (Africa) - Range of habitat and degree of infestation - Development cycle. Doctoral thesis, USTL, Montpellier, France. 241 p. **[Google scholar]**

Lebrun J.P, Stork A. 1991-7. Enumeration of flowering plants of Tropical Africa. Vol I, Vol II, Vol III, Vol IV. Ed. Conservatories and botanical gardens of the city of Geneva. **[Google scholar]**

Lebrun J. 1966. Biological forms in tropical vegetation. *Bull Soc Bot*. 164-175. **[Google scholar]**

Lopes Ovejero R.F, Soares D.J, Oliveira W.S, Fonseca L.B, Berger G.U, Soteres J.K, Christoffoleti P.J. 2013. Residual herbicides inweed management for glyphosateresistant soybean in Brazil. *Planta Daninha*. 31(4): 947-959. **[Crossref]**, **[Google scholar]**, **[Publisher]**

MAH. 2004. Biliographic study on the rice sector in Senegal. Senegal National Rice Observatory (O.N.R.S), Senegal. **[Google scholar]**

Maillet J. 1981. Evolution of the weed flora in Montpellier under the pressure of cultivation techniques. Doctor's thesis. USTL. Montpellier. 200 p. **[Google scholar]**

Mballo R. 2019. Irrigated rice weed communities in the Senegal River valley: flora structure, habitat range, species infestation levels and improvement of weed management. Single Doctorate Thesis. Ckeikh Anta Diop University of Dakar, 180 p. **[Google scholar]**

Mbaye M.S. 2013. Millet [*Pennisetum glaucum* (L.) R.Br] and cowpea [*Vigna unguiculata* (L.) Walp.] Association: Spatiotemporal arrangement of cultures, structures, dynamics and competition of weed flora and proposal of a technical itinerary. State doctorate thesis. Ckeikh Anta Diop University of Dakar. 236 p. **[Google scholar]**

Mehdizadeh M. 2019. Sensitivity of oilseed rape (*Brassica napus* L.) to soil residues of imazethapyr herbicide. *Int J Agric Environ Food Sci*. 3: 46-49. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Ndione Y.C. 2010. Impact of agricultural policies on food security in Senegal. Master's thesis, Cheikh Anta Diop University of Dakar. 60p. **[Google scholar]**

Noba K. 2002. Weed flora in the south of the Arachidier Basin (Senegal): structure, dynamics and impact on millet and peanut production.State Doctorate Thesis in Plant Biology. Option Weed, FST, UCAD, Dakar. 158 p. **[Google scholar]**

Posner J.L, Crawford E.W. 1991. An agro-economic analysis of field trials from a farming systems research perspective - weed control in rain-fed lowland rice in Senegal. *Exp Agricul*. 27: 231-241. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Rahman A, Dowsett C.A, Trolove M.R. James T.K. 2014 - Soil residual activity and plant-back periods for the herbicides saflufenacil and topramezone. AgResearch, Ruakura research centre, Hamilton, New Zealand. **[Crossref]**, **[Google scholar]**

Raunkier C. 1934. The life forms of plants and statistical Plants Geography. Ed. Clarendron, Press, Oxford. 623p. **[Google scholar]**

Rodenburg J, Johnson D.E. 2009. Weed Management in Rice-Based Cropping Systems in Africa. *Adv Agron*. 103 : 149-218. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Rodenburg J, Zossou-Kouderin N, Gbèhounou G, Ahanchede A, Touré A, Kyalo G, Kiepe P. 2011. *Rhamphicarpa fistulosa*, a parasitic weed threatening rain-fed lowland rice production in sub-Saharan Africa - A case study from Benin. *Crop Prot*. 30(10): 1306-1314. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Saito K, Azoma K, Rodenburg J. 2010. Plant characteristics associated with weed competitiveness of rice under upland and lowland conditions in West Africa. *Field Crops Res*. 116: 308-317. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Sylla M, Traore K, Soro D, Yode T.E.G. 2017. Assessment of weed management practices in irrigated rice cultivation in the locality of Daloa, center-west of the Ivory Coast. *African Agron*. 29(1): 49-64. **[Google scholar]**

Traore H, Maillet J. 1992. Flore adventice des cultures céréalières annuelles du Burkina-Faso. *Weed Res*. 32: 279-293. **[Crossref]**, **[Google scholar]**, **[Publisher]**