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Weed control in direct-seeded lowland rice under poor water control conditions

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Summary: Résumé: Zusammenfassung

Several herbicides applied singly and in combination were evaluated for weed control and for their effects on crop yield in direct-seeded lowland rice under poor water management conditions characteristic of the conditions in which lowland rice is grown by most farmers in West Africa. Several herbicides including cyperquat at 3·0 kg/ha, a mixture of cyperquat and 2,4-D at 2·0+0·5 kg/ha, bentazon at 2·0 kg/ha and avirosan satisfactorily controlled sedges in the 3-year study. Crop yield was consistently high in plots where weeds were controlled with post-emergence application of MCPA+propanil at 1·0+1·7 kg/ha, propanil+thiobencarb 2·2+1·2 kg/ha, oxadiazon 1·5 kg/ha, bentazon 2·0, granular 2,4-D at 1·0 kg/ha, and a pre-emergence application of bifenox at 2·0 kg/ha. Crop yields in plots treated with these herbicides were generally better than with two hand-weedings.

Desherbage des riz de bas fond cultivés en semis direct sous des conditions à faible régime hydrique

L'efficacité et la sélectivité de plusieurs herbicides appliqués seuls ou en association ont été testées sur des riz de bas fond cultivés en semis direct sous des conditions à faible régime hydrique, caractéristiques de la culture des riz de bas fond en Afrique de l'Ouest. Plusieurs matières actives, en particulier le cyperquat à 3 kg/ha, un mélange de 2,4-D et de cyperquat à 2 kg+0·5 kg/ha, la bentazone à 2 kg/ha et l'avirosan ont assuré un désherbage satisfaisant détruisant notamment les cyperacés dans cette expérimentation de 3 années. Les gains de rendement ont été importants dans les parcelles où les mauvaises herbes étaient éliminées avec des traitements de post-levée de MCPA+propanil 1 kg+1·7 kg/ha, propanil+thiobencarb 2·2+1·2 kg/ha, oxadiazon 1·5 kg/ha, bentazone 2·0 kg/ha, 2,4-D granulé à 1·0 kg/ha et un traitement de prélevée mettant en jeu 2·0 kg/ha de bifenox. Les rendements dans les parcelles traitées avec ces herbicides étaient en général supérieurs à ceux obtenus avec deux désherbages manuels.

Unkrautbekämpfung in gesätem Wasserreis bei unzureichend kontrollierten Bewässerungsbedingungen

Verschiedene Herbizide wurden in einfacher und kombinierter Anwendung auf ihren Unkrautbekämpfungserfolg und ihren Einfluss auf den Ertrag in gesätem Wasserreis unter den bei den meisten Bauern in Westafrika üblichen unzureichend kontrollierten Bewässerungsbedingungen untersucht. Verschiedene Herbizide einschliesslich Cyperquat mit 3,0 kg/ha, eine Mischung von Cyperquat und 2,4-D mit 2,0+0,5 kg/ha, Bentazon mit 2,0 kg/ha und Avirosan bekämpften in einem 3 jährigen Versuch Seggen mit befriedigendem Erfolg. Der Ertrag war durchgehend hoch auf Flächen, auf denen Unkräuter im Nachauflauf mit MCPA+Propanil mit 1,0+1,7 kg/ha, Propanil+Thiobencarb mit 2,2+1,2 kg/ha, Oxadiazon mit 1,5 kg/ha, Bentazon mit 2,0 kg/ha und granuliertem 2,4-D mit 1,0 kg/ha bekämpft wurden sowie bei einer Vorauflaufbehandlung mit Bifenox mit 2,0 kg/ha. Der Reisertrag der mit

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Herbiziden behandelten Parzellen war allgemein besser als auf solchen, die zweimal von Hand gejätet wurden.

Introduction

West Africa produces about 35% of the rice grown in Africa, and Nigeria ranks first in total rice production in this region (FAO, 1978). Although average rice yield in Nigeria and other West African countries is less than 2·0 t/ha (mainly as a result of large-scale upland rice production), lowland rice yields reported in various experimental station and extension demonstration plots in Nigeria show yield averages of 4–6 tons/ha (Williams, 1969; 1975; IITA, 1974; 1978). Yields in farmers' fields lag behind the experiment station results partly because of the low-yielding cultivars traditionally used by farmers and as a result of several other factors including poor land levelling and water management (Akobundu and Fagade, 1978). Generally, these farmers lack equipment for proper land preparation and have to make do with locally available hoes. In most places in West Africa, floodwater is the main source of water for the paddy. Time of flood onset, and water distribution are completely beyond the farmers' resources to handle.

Yield reduction in lowland rice caused by weeds could be minimized if proper water management was possible (Martin & Guegan, 1973; Smith, 1970). Direct-seeded rice is generally more susceptible to weed infestation than transplanted rice but, when weeds are properly controlled, direct-seeded lowland rice can yield as well as transplanted rice (De Datta *et al.*, 1969). With proper weed control, direct-seeding of rice should provide an attractive, low-labour-intensive method of rice production.

Bentazon, bifenox, fluorodifen, molinate and thiobencarb are herbicides which have been shown to perform well in lowland rice where good land preparation coupled with proper water management is practised (IITA, 1974; Williams, 1975; Smith, 1970; Dean *et al.*, 1977; Atwell *et al.*, 1978). These herbicides performed very poorly when used in hydromorphic soils (IITA, 1974; 1976) or in conditions of poor soil preparation and water management in farmers' fields in Nigeria and other parts of West Africa. Chemical weed control in rice must therefore focus on identifying herbicides and herbicide combinations that will provide good weed control and depend less on ideal water management to suppress weeds.

Materials and methods

The experiments reported here were done over a 3-year period in a rice paddy that was previously fallowed for more than 1 year and was heavily infested with weeds. The levelling of the paddy was not good enough to prevent uneven water distribution. The experimental area was first sprayed with paraquat at 0·5 kg/ha, and later rotovated. It was flooded and puddled within 2 days of initial rotovation. Mixed fertilizer at the rate 20 kg/ha N, 60 kg/ha P_2O_5 and 30 kg/ha K_2O was worked into the mud prior to partitioning the field into 3-m-wide strips. The strips were bunded so as to provide irrigation channel 0·5 m wide between adjacent strips.

Each strip was later subdivided with smaller bunds into self-contained 3 × 5m plots. Rice seeds that were soaked overnight in water were drilled at a seed-rate of 60 kg/ha in rows 30 cm apart along the length of the 3-m-wide strips. To ensure seed coverage, dry soil was lightly sprinkled on the seeds. Pre-emergence herbicides were applied broadcast on the wet soil with a knapsack sprayer calibrated to deliver 350 l/ha of spray volume. Rice seedlings emerged 5 days after seeding. Post-emergence herbicide treatments were applied at specified time intervals relative to the time of seeding (Tables 1–3).

The experiment was set up as a randomized complete block design with three replications. Water was periodically let into the plots in such a manner as to keep the water level at a depth of about 2 cm. This water level is not enough to suppress weeds and is typical of the shallow flooding that occurs in 'high' spots of poorly levelled fields. These are usually the areas of poor weed control. The crop was visually rated for herbicide injury 4 weeks after crop seeding, and for weed control at 8 weeks after seeding except where otherwise stated. Additional data collected were dry weight of weeds and rice grain yield. Weeds and rice were harvested from net plot areas of 7·5 m^2 and 9 m^2 respectively. Rice grain was weighed and moisture corrected to 14%. The 1977 and 1978 experimental designs and layouts were identical with those of 1976. The rice cultivar TOs 42 (IR 665) used in the 1976 trial was replaced with BG-90-2 in the subsequent years.

Results

In the 1976 experiment, uncontrolled weed growth caused 55% reduction in rice yield. Weeds present in the control plots were *Heteranthera* spp., *Sphenochloa zeylanica* Gaertn., *Alternanthera sessilis* (L.) R. Br. ex Roth, *Pentodon pentandrus* (Schum. & Thonn.) Vatke, *Pycreus* spp., *Cyperus difformis* L. and *Fimbrystylis* spp. The sedges constituted more than 75% of total weeds in the unweeded check (Table 1). Grasses were generally absent in this field. Most of these weeds were present in this field during the 1977 and 1978 experiments. Uncontrolled weed growth in the 1977 and 1978 experiments caused yield reductions of 61 and 44% respectively (Tables 2 and 3).

The effects of various herbicides on weed growth and paddy yield over a 3-year period are shown in Tables 1–3. In the 1976 experiment the pre-emergence herbicides bifenox at 2·0 kg/ha and avirosan at 2·5 kg/ha satisfactorily controlled weeds. Although some reduction in stand and vigour were observed in the avirosan treated plots, crop yield in plots treated with these pre-emergence herbicides was similar to that from the weed-free and the hand-weeded plots. Consistently good weed control and crop yield were observed in plots treated with these herbicides in the 1977 and 1978 experiments. Oxadiazon at 1·5 kg/ha applied pre-emergence effectively controlled both broadleaves and sedges and crop yield was good in the 2 years that the herbicide was evaluated (Tables 2 and 3).

Excellent crop yield with acceptable weed control was obtained in plots treated with post-emergence applications of bentazon, cyperquat, formulated mixture of MCPA + propanil or propanil + thiobencarb, and granular 2,4-D. These

Table 1 Effect of herbicide treatments on weed control and grain yield in rice TOs 42 (1976)

Treatments	Rate (kg a.i./ha)	Time	Weed control rating†		Crop† injury rating	Dry weight of weeds‡ (kg/ha)		Grain yield (kg/ha)
			BL	S		BL	S	
Fluorodifen + propanil	1·5 + 2·0	21 DAS*	93	98	0	4	101	5920
Weed-free	—	—	100	100	0	0	0	5310
Bifenox	2·0	Pre-em.	97	92	15	0·7	40	5090
Bentazon	2·0	14 DAS	93	95	8	1	52	5060
Propanil + thiobencarb	1·7 + 1·6	14 DAS	98	100	0	6	74	5027
Propanil + thiobencarb	2·2 + 2·0	7 DAS	98	98	0	3	86	4877
Hand-weeding	—	14 + 42 DAS	95	100	0	8	8	4767
2,4-D (granules)	0·75	35 DAS	56	92	0	21	21	4723
Avirosan	2·5	Pre-em.	93	97	25	4	5	4633
Molinate	4·0	14 DAS	58	95	0	53	215	4610
Molinate (granules)	3·0	14 DAS	70	96	0	21	139	4597
Molinate	3·0	14 DAS	27	94	0	71	56	4450
Propanil + thiobencarb	2·2 + 2·0	14 DAS	71	100	0	15	40	4307
Cyperquat	3·0	48 DAS	62	78	0	46	0	4177
Propanil + thiobencarb	2·2 + 2·0	21 DAS	99	99	0	0·7	126	4103
Propanil	3·2	14 DAS	95	96	0	1	103	4013
Cyperquat + 2,4-D	2·0 + 0·5	28 DAS	98	100	0	2	1	3973
Thiobencarb	3·0	14 DAS	78	89	0	294	42	2863
Unweeded check	—	—	0	0	0	139	413	2373
LSD $P = 0{\cdot}05$			29	9		190	99	1779

* DAS = Days after seeding.

† Weed control and crop rating. Weed control and crop injury rated at 56 and 28 DAS respectively. Rating scale: 0 = no weed control or crop injury; 80 = satisfactory to good control; 100 = complete weed destruction.

‡ Dry weight taken at crop harvest. BL = broadleaves; S = sedges.

Table 2 Effect of herbicide treatment on weed control and crop yield BG-90-2 (1977)

Treatments	Rate (kg a.i./ha)	Time	Weed control rating* BL	Weed control rating* S	Dry weight of weeds (kg/ha)	Grain yield (kg/ha)
MCPA + propanil	1·0 + 2·9	14 DAS*	86	94	284	4877
Propanil + thiobencarb	2·2 + 1·2	7 DAS	94	97	86	4787
Weed-free	—	—	100	100	0	4747
Propanil + thiobencarb	1·7 + 1·2	14 DAS	94	99	69	4670
Oxadiazon	1·5	Pre-em.	95	96	37	4583
Molinate (granules)	3·0	14 DAS	80	91	374	4577
Cyperquat	2·5	28 DAS	82	92	98	4477
Bifenox	2·0	Pre-em.	92	98	84	4420
Propanil + thiobencarb	2·2 + 1·2	14 DAS	92	95	44	4410
2,4-D (granules)	1·0	21 DAS	87	80	132	4407
Cyperquat + 2,4-D	1·5 + 0·5	28 DAS	85	96	67	4383
Bentazon	3·0	14 DAS	93	96	158	4313
Avirosan	2·5	Pre-em.	89	92	56	4150
Fluorodifen + propanil	1·5 + 2·0	21 DAS	90	95	148	3857
Handweeding	—	7 + 35 DAS	89	97	325	3707
Molinate	4·0	14 DAS	87	96	339	3603
Molinate	3·0	14 DAS	79	93	398	3280
Propanil	3·6	14 DAS	32	70	834	2777
2,4-D (granules)	0·75	21 DAS	85	89	203	2703
Unweeded check	—	—	0	0	748	1833
LSD $P = 0{\cdot}05$			9·3	9·8	189	1464

* See Table 1 for explanation.
Weed control rating was at 42 DAS. Weed dry weight taken at crop harvest.

Table 3 Effect of herbicide treatments on weed control and rice grain yield BG-90-2 (1978)

Treatment	Rate (kg a.i./ha)	Time	Weed control rating* BL	Weed control rating* S	Crop* injury	Dry weight of weeds (kg/ha)	Grain yield (kg/ha)
MCPA + propanil	1·0 + 1·7	14 DAS*	97	92	15	83	6250
Propanil + thiobencarb	2·2 + 1·2	14 DAS	95	100	0	10	5963
2,4-D (granules)	1·0	14 DAS	92	100	2	84	5493
2,4-D (granules)	1·0	21 DAS	95	97	8	62	5343
Propanil + thiobencarb	2·2 + 1·2	21 DAS	92	100	0	165	5333
Bentazon	2·0	14 DAS	100	100	3	14	5317
Oxadiazon	1·5	Pre-em.	100	100	30	19	5317
Bentazon	3·0	14 DAS	97	100	0	14	5213
Butachlor + propanil	1·6 + 2·9	14 DAS	100	100	10	19	5047
Propanil + thiobencarb	2·2 + 1·2	7 DAS	100	100	0	21	5030
Cyperquat	2·5	14 DAS	62	83	0	19	4850
Fluorodifen + propanil	5·0	14 DAS	89	100	13	30	4850
Weed-free	—	—	100	100	0	18	4827
Hand-weeding	—	24 + 42 DAS	91	84	0	21	4710
Bifenox	2·0	Pre-em.	100	100	8	5	4693
Cyperquat	2·5	28 DAS	30	38	0	49	4577
Fluorodifen + propanil	6·0	14 DAS	83	100	20	71	4477
Propanil	3·6	14 DAS	94	47	7	159	4093
Unweeded check	—	—	0	0	0	283	3523
LSD $P = 0{\cdot}05$			20·7	24·8		127	1150

* See Table 1 for explanation.
Weed control rating was at 42 DAS. Crop injury rating was at 28 DAS. Dry weight taken at crop harvest.

results were consistent in all the experiments. Although crop yields in molinate-treated plots were good in the 3-year study, weed control was generally poor compared to the other herbicides. Granular 2,4-D was more effective at 1·0 kg/ha than at a lower rate. Crop yield was generally better with these herbicides than with hand-weeding although the yield difference between the hand-weeded plots and the herbicide treated plots were not significant. Crop yield in the propanil treated plot was as poor as the unweeded control, however, a mixture of this herbicide with either thiobencarb or MCPA gave significantly higher crop yield in each of the experiments.

Discussion

Results of the 3-year study show that good crop yield and weed control can be obtained in direct-seeded lowland rice without good water control provided that weeds are adequately controlled. Minimizing weed competition until the crop is fully established is necessary when the traditional role of flooding as a weed control tool in lowland rice (Jenkins & Jones, 1944) is lost due to poor water control, or when water was kept at the shallow depth maintained in this study. According to Smith (1970), most aquatic weeds grow best in shallow water (less than 5 cm deep) and flooding rice fields to a depth of 10–20 cm helps to control even such troublesome weeds as *Echinochloa* spp.

The extent of yield reduction in the unweeded plot in each experiment varied with the weed pressure in that year. Yield loss in the unweeded plot was higher in the 1977 experiment than in the 1976 and 1978 experiments and it was in this experiment that the highest weed biomass was recorded in the 3-year study.

Generally, crop yield was high in those plots where good weed control was maintained throughout the rice growth period. This was particularly true of pre-emergence applications of bifenox at 2·0 kg/ha and oxadiazon at 1·5 kg/ha and of post-emergence applications of 2,4-D granular formulation, and mixtures of propanil + thiobencarb, and MCPA + propanil. Although crop yield was not significantly reduced in such treatments as granular molinate application (Tables 1 and 2), high weed biomass at crop harvest could increase harvesting cost and reduce crop quality.

Several of the herbicides used in this study controlled weeds effectively and crop yield was as good as in the weedfree plots. For some herbicides, the difference between good and poor weed control was related to the timing of the application. For example, a formulated mixture of propanil and thiobencarb gave consistently good weed control and high crop yield when applied post-emergence to both crop and weeds within the first 2 weeks after weeding. Delaying the application by 3 weeks resulted in poor weed control. This mixture was however not very effective against sedges. The best sedge control was obtained with cyperquat. The effectiveness of this herbicide in controlling sedges has been reported previously (Schwartzbeck, 1976).

The granular formulation of 2,4-D and molinate not only controlled weeds satisfactorily but also gave crop yields comparable to the best hand-weeded treatments. Although the granular formulation of molinate has been reported to be more effective in controlling weeds than the liquid formulation (Oelke & Morse, 1968) weed weight at crop harvest was identical in both formulations under the conditions of our study (Tables 1 and 2). Crop yield was however significantly higher in plots treated with the granular formulation than in plots treated with the same rate of a liquid formulation (Table 2). Granular formulation of 2,4-D was also effective in controlling weeds in all of the trials. However, De Datta (1978) noted that 2,4-D granules failed to control weeds where there was no standing water for up to 20 days after transplanting rice.

Granular herbicides offer many advantages, such as ease of application, to the small farmer. These farmers have been estimated as producing 95% of the West African rice (de Boer, 1974). Granular herbicides do not necessarily require special equipment to apply them. The farmer can easily broadcast them uniformly with a little practice since most of these farmers are already familiar with broadcast seeding of rice fields.

One of the attractions of direct seeding of rice is its saving on the labour necessary for establishing and transplanting rice seedlings. Direct seeding can be made even more attractive if weeds are chemically controlled. Herbicides that have shown superior weed control under poor water management conditions have been identified for a wide range of weed problems. Since most peasant rice fields share the problem of poor land levelling and water control, weed control methods that take these problems into consideration stand a good chance of meeting the needs of a majority of these farmers. In Nigeria and other West African countries, water control in rice fields goes beyond the small farmer's technical and economic resources. More effort should therefore be put into improving the farmer's ability to cope with weeds and, this is best done by evaluating herbicides under conditions that closely approximate to those of the farmer's. Any herbicide that controls weeds effectively under these conditions will naturally be expected to perform even better under improved water management practices.

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