Studies on the sensitivity of Azolla species to rice herbicides

N. SENTHIL KUMAR AND R. JAYAKUMAR

Dept. of Soil Science & Agrl. Chemistry, Tamil Nadu Agrl. University, Coimbatore - 641 003, Tamil Nadu

Abstract: Laboratory and green house experiments were conducted during 2002 to find out the sensitivity of different Azolla species to rice herbicides. From the screening experiment in the laboratory, three herbicides viz. anilofos 0.4 kg ha⁻¹, butachlor 1.25 kg ha⁻¹ and clomazone 0.3 kg ha⁻¹ and four species of Azolla viz., A. microphylla, A. filiculoides, TNAU hybrid and Rong Ping hybrid at 500 kg ha⁻¹ were chosen and compared independently and in different combinations in the pot culture experiment. Rice var. CO 47 was raised under green house conditions and the experiment was carried out under FRBD with 3 replications. The growth, yield and yield parameters were recorded after imposing the treatments. The results revealed that combination of clomazone 0.3 kg ha⁻¹ and A. microphylla performed significantly superior with respect to plant growth, yield attributes and yield. Among the herbicides tried, clomazone application at 03 kg ha⁻¹ showed an increase in plant growth characters, yield attributes and yield. Between the individual Azolla species, A. microphylla recorded the highest grain yield and was on par with A. filiculoides.

Key words: Clomazone, Azolla species, Growth, Yield parameters, Yield.

Introduction

Worldwide, India stands first in rice area with 43 million hectare and second in rice production (199 million tonnes), after China (Anon, 2001) contributing 31.0 per cent of global rice production (Brar and Walia, 2001). Demand for rice is increasing and an additional 300 million tonnes per year has to be produced by 2025 (Swaminathan, 1998). Approaches to achieve this demand include expanding the rice area (horizontal expansion) increasing the yield (vertical expansion), shrinking the yield gap and reducing yield losses. Weed infestation is one of the major constraints responsible for low yields of rice in India. Several studies conducted in India and abroad indicate that weed incidence in low land situation accounts for a yield loss of 11-12 per cent in transplanted rice (Ghosh and Moorthy, 1998). Reliance on herbicides for weed control is expected to continue because there is no other attractive superior technology available (Singh and Bhan, 1998).

Azolla is a free floating aquatic fern that assimilates nitrogen in symbiotic association with the cyanobacterial symbiont, Anahaena Azolla. Biological nitrogen fixation (BNF) through Azolla-Anabaena complex could contribute 40-60 kg N ha⁻¹ in one crop of rice and is considered

to be a potential biological system for increasing rice yield at comparatively low cost in lowland rice cultivation. The important factor in using Azolla as biofertilizer for rice crop, is its quick decomposition in soil and better availability of nitrogen. Britto and Seethalakshmi (2002) reported that increased concentration of 2,4-D decreased the biomass and chlorophyll content of two Azolla species viz. A. microphylla and A. filculoites.

The integration of Azolla and herbicides in rice cultivation was found to be superior over other treatments, which registered the synergistic interaction or improved weed reduction or yield increment when used in combination (Kathiresan et al. 2002). Hence the present investigation was undertaken to study the sensitivity of Azolla species to rice herbicides.

Materials and Methods

A laboratory study was carried out for fixing the treatment combination for pot culture experiment, by using five herbicides (anilofos, butachlor, clomazone, 2,4-D and metsulfuran methyl) at recommended (x) and double the recommended (2x) dose compared with control and with four species of Azolla grown under water (50 ml water + 0.5 g Azolla) and soil

Table 1. Effect of herbicides and Azolla speices on biomass (g) grown under water and soil medium

Treatment details Herbicide	0.450 0.840 0.430 0.635 0.589 0.535 0.825 0.495 0.585 0.610 0.460 0.580 0.425	0.540 0.695 0.580 0.840 0.664 0.475 0.655 0.535 0.770 0.609	0.407 0.742 0.503 0.660 0.415 0.740 0.542 0.728	0.645 0.670 0.630 0.795 0.685 0.740 0.725 0.740 0.690 0.724	0.630 0.665 0.635 0.580 0.627 0.970 0.785 0.765 0.740 0.815	0.605 0.760 0.585 0.765 0.679 0.480 0.515 0.705 0.535	0.627 0.698 0.617 0.713 0.730 0.675 0.737
H ₁ Anilofos a ₁ 0.230 a ₂ 0.690 a ₃ 0.500 a ₄ 0.505 Mean 0.481 H ₂ Butachlor a ₁ 0.235 a ₂ 0.740 a ₃ 0.595 a ₄ 0.830 Mean 0.600 H ₃ Clomazone a ₁ 0.330 a ₂ 1.045 a ₃ 0.650 a ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.645 a ₄ 0.635	0.840 0.430 0.635 0.589 0.535 0.825 0.495 0.585 0.610 0.460 0.580	0.695 0.580 0.840 0.664 0.475 0.655 0.535 0.770 0.609	0.742 0.503 0.660 0.415 0.740 0.542 0.728	0.670 0.630 0.795 0.685 0.740 0.725 0.740 0.690	0.665 0.635 0.580 0.627 0.970 0.785 0.765 0.740	0.760 0.585 0.765 0.679 0.480 0.515 0.705 0.535	0.698 0.617 0.713 0.730 0.675 0.737
H ₁ Anilofos a ₁ 0.230 a ₂ 0.690 a ₃ 0.500 a ₄ 0.505 Mean 0.481 H ₂ Butachlor a ₁ 0.235 a ₂ 0.740 a ₃ 0.595 a ₄ 0.830 Mean 0.600 H ₃ Clomazone a ₁ 0.330 a ₂ 1.045 a ₃ 0.650 a ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.645 a ₄ 0.635	0.840 0.430 0.635 0.589 0.535 0.825 0.495 0.585 0.610 0.460 0.580	0.695 0.580 0.840 0.664 0.475 0.655 0.535 0.770 0.609	0.742 0.503 0.660 0.415 0.740 0.542 0.728	0.670 0.630 0.795 0.685 0.740 0.725 0.740 0.690	0.665 0.635 0.580 0.627 0.970 0.785 0.765 0.740	0.760 0.585 0.765 0.679 0.480 0.515 0.705 0.535	0.698 0.617 0.713 0.730 0.675 0.737
A	0.840 0.430 0.635 0.589 0.535 0.825 0.495 0.585 0.610 0.460 0.580	0.695 0.580 0.840 0.664 0.475 0.655 0.535 0.770 0.609	0.503 0.660 0.415 0.740 0.542 0.728	0.630 0.795 0.685 0.740 0.725 0.740 0.690	0.635 0.580 0.627 0.970 0.785 0.765 0.740	0.585 0.765 0.679 0.480 0.515 0.705 0.535	0.617 0.713 0.730 0.675 0.737
A ₃ 0.500 a ₄ 0.505 Mean 0.481 H ₂ Butachlor a ₁ 0.235 a ₂ 0.740 a ₃ 0.595 a ₄ 0.830 Mean 0.600 H ₃ Clomazone a ₁ 0.330 a ₂ 1.045 a ₃ 0.650 a ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.645 a ₄ 0.645 a ₅ 0.645 a ₆ 0.435	0.430 0.635 0.589 0.535 0.825 0.495 0.585 0.610 0.460 0.580	0.580 0.840 0.664 0.475 0.655 0.535 0.770 0.609	0.660 0.415 0.740 0.542 0.728	0.795 0.685 0.740 0.725 0.740 0.690	0.580 0.627 0.970 0.785 0.765 0.740	0.765 0.679 0.480 0.515 0.705 0.535	0.713 0.730 0.675 0.737
A 0.505 Mean 0.481 H ₂ Butachlor a 0.235 a ₂ 0.740 a ₃ 0.595 a ₄ 0.830 Mean 0.600 H ₃ Clomazone a 0.330 a ₂ 1.045 a ₃ 0.650 a ₄ 0.590 Mean 0.654 H ₄ 2,4-D a 0.180 a ₂ 0.785 a ₃ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a 0.645 a 0.435	0.635 0.589 0.535 0.825 0.495 0.585 0.610 0.460 0.580	0.840 0.664 0.475 0.655 0.535 0.770 0.609 0.565	0.660 0.415 0.740 0.542 0.728	0.685 0.740 0.725 0.740 0.690	0.627 0.970 0.785 0.765 0.740	0.679 0.480 0.515 0.705 0.535	0.730 0.675 0.737
Mean 0.481 H ₂ Butachlor a ₁ 0.235 a ₂ 0.740 a ₃ 0.595 a ₄ 0.830 Mean 0.600 H ₃ Clomazone a ₁ 0.330 a ₂ 1.045 a ₃ 0.650 a ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.645 a ₄ 0.645 a ₅ 0.645	0.589 0.535 0.825 0.495 0.585 0.610 0.460 0.580	0.664 0.475 0.655 0.535 0.770 0.609 0.565	0.415 0.740 0.542 0.728	0.740 0.725 0.740 0.690	0.970 0.785 0.765 0.740	0.480 0.515 0.705 0.535	0.675
H ₂ Butachlor a ₁ 0.235 a ₂ 0.740 a ₃ 0.595 a ₄ 0.830 Mean 0.600 H ₃ Clomazone a ₁ 0.330 a ₂ 1.045 a ₃ 0.650 a ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.535 a ₄ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.645 a ₄ 0.435	0.535 0.825 0.495 0.585 0.610 0.460 0.580	0.475 0.655 0.535 0.770 0.609 0.565	0.740 0.542 0.728	0.740 0.725 0.740 0.690	0.970 0.785 0.765 0.740	0.515 0.705 0.535	0.675
A 2 0.740 A 3 0.595 A 4 0.830 Mean 0.600 H ₃ Clomazone A 0.330 A 1.045 A 0.650 A 0.590 Mean 0.654 H ₄ 2,4-D A 0.180 A 0.785 A 0.625 Mean 0.531 H ₅ Metasul- furan methyl A 0.645 A 0.645 A 0.645	0.825 0.495 0.585 0.610 0.460 0.580	0.655 0.535 0.770 0.609 0.565	0.740 0.542 0.728	0.725 0.740 0.690	0.785 0.765 0.740	0.515 0.705 0.535	0.675
A 2 0.740 A 3 0.595 A 4 0.830 Mean 0.600 H ₃ Clomazone A 0.330 A 1.045 A 0.650 A 0.590 Mean 0.654 H ₄ 2,4-D A 0.180 A 0.785 A 0.625 Mean 0.531 H ₅ Metasul- furan methyl A 0.645 A 0.645 A 0.645	0.495 0.585 0.610 0.460 0.580	0.535 0.770 0.609 0.565	0.542 0.728	0.740 0.690	0.765 0.740	0.705	0.737
A ₃ 0.595 A ₄ 0.830 Mean 0.600 H ₃ Clomazone a ₁ 0.330 A ₂ 1.045 A ₃ 0.650 A ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 A ₂ 0.785 A ₃ 0.535 A ₄ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 A ₃ 0.645 A ₄ 0.435	0.495 0.585 0.610 0.460 0.580	0.770 0.609 0.565	0.728	0.690	0.740	0.535	
A 0.830 Mean 0.600 H ₃ Clomazone a 0.330 a 1.045 a 0.650 a 0.590 Mean 0.654 H ₄ 2,4-D a 0.180 a 0.785 a 0.625 Mean 0.531 H ₅ Metasul- furan methyl a 0.645 a 0.435	0.585 0.610 0.460 0.580	0.770 0.609 0.565					
Mean 0.600 H ₃ Clomazone a ₁ 0.330 a ₂ 1.045 a ₃ 0.650 a ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.645 a ₄ 0.635	0.610 0.460 0.580	0.609 0.565	118411772	0.724	0.815		0.655
H ₃ Clomazone a ₁ 0.330 a ₂ 1.045 a ₃ 0.650 a ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.535 a ₄ 0.625 Mean 0.531 H ₅ Metasul- a ₁ 0.335 furan methyl a ₂ 0.645 a ₃ 0.435	0.460 0.580	0.565	02012241			0.559	-
A 1.045 a 0.650 a 0.590 Mean 0.654 H ₄ 2,4-D a 0.180 a 0.785 a 0.625 Mean 0.531 H ₅ Metasul- furan methyl a 0.645 a 0.645 a 0.645	0.580		0.452	0.500	0.480	0.675	0.552
A ₂ 1.045 A ₃ 0.650 A ₄ 0.590 Mean 0.654 H ₄ 2,4-D A ₁ 0.180 A ₂ 0.785 A ₃ 0.535 A ₄ 0.625 Mean 0.531 H ₅ Metasul- furan methyl A ₂ 0.645 A ₃ 0.435			0.452	0.830	0.625	0.580	0.678
A ₃ 0.650 A ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.535 a ₄ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₄ 0.645 a ₅ 0.645	0.425	0.685	0.770		0.670	0.640	0.753
A ₄ 0.590 Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.535 a ₄ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.435		0.485	0.520	0.950		0.830	0.688
Mean 0.654 H ₄ 2,4-D a ₁ 0.180 a ₂ 0.785 a ₃ 0.535 a ₄ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.435	0.870	0.680	0.713	0.670	0.565		0.000
a ₂ 0.785 a ₃ 0.535 a ₄ 0.625 Mean 0.531 H ₅ Metasul- a ₁ 0.335 furan methyl a ₂ 0.645 a ₃ 0.435	0.584	0.604		0.737	0.585	0.681	
a ₂ 0.785 a ₃ 0.535 a ₄ 0.625 Mean 0.531 H ₅ Metasul- a ₁ 0.335 furan methyl a ₂ 0.645 a ₃ 0.435	0.370	0.495	0.348	0.880	0.630	0.695	0.735
A ₃ 0.535 a ₄ 0.625 Mean 0.531 H ₅ Metasul- a ₁ 0.335 furan methyl a ₂ 0.645 a ₃ 0.435	0.565	0.705	0.685	0.780	0.735	0.695	0.737
a ₄ 0.625 Mean 0.531 H ₅ Metasul- furan methyl a ₂ 0.645 a ₃ 0.435	0.570	0.785	0.630	0.325	0.590	0.615	0.510
Mean 0.531 H ₅ Metasul- a ₁ 0.335 furan methyl a ₂ 0.645 a ₃ 0.435	0.545	0.810	0.660	0.780	0.525	0.875	0.727
H ₅ Metasul- a ₁ 0.335 furan methyl a ₂ 0.645 a ₃ 0.435	0.512	0.699	0.000	0.691	0.620	0.720	. 11
furan methyl a ₂ 0.645 a ₃ 0.435			05/19/2020			41914.119749	0.000
furan methyl a_2 0.645 a_4 0.435	0.500	0.570	0.468	0.275	0.775	0.995	0.682
a 0.435	0.660	0.775	0.693	0.270	0.975	0.525	0.590
0 545	0.505	0.480	0.473	0.485	0.630	0.540	0.557
a, 0.545	0.640	0.880	0.688	0.675	0.690	0.735	0.700
Mean 0.490	0.576	0.676		0.426	0.767	0.699	
	SEd	CD (0.05)	<u> </u>		SEd	CD (0.05)
H	0.006	0.012			0.015	0.029	
a ·	0.005	0.010			0.013	0.026	24
ď	0.005	0.009			0.011	0.023	ñ
Ha	0.012	0.014			0.029	0.058	
ad ,	0.009	0.018			0.023	0.045	
Hd	0.010	0.020			0.025	0.051	
Had	0.020	0.020			0.023	0.101	
			TOTAL T				ribei d
a, - A. microphylla, a2	- A. filcul	oides,	a, - TNAU	hybrid,	$a_4 - Rc$	ng Ping h	yond

(20 g soil + 50 ml water + 0.5 g Azolla) medium in petri plates with two replications. From the screening study, three herbicides (anilofos, butachlor, clomazone) with four species of Azolla were screened for pot culture experiment. Pot culture experiment was conducted during February 2002 at Department of Soil Science and Agricultural

Chemistry, TNAU, Coimbatore with CO-47 cultivator of rice in FRBD with three replications. The treatments include the three selected herbicide at recommended and double the recommended doses and four Azolla species at 500 kg has alone and in combination constituting twent treatments. Common recommended fertilizer dos

2
5
mracters
cun
ξ
I Brow
50
1177
٦.
5
5
5
4
3
3
HILL / 140 FEE
1
2
CAPITAL
3
;
3
5
5

1
1

a ₁ a ₂ 49.50 53.50 48.90 52.60 50.10 57.03 45.80 48.20 48.57 52.83 H 0.29 0.5) 0.60 4.70 6.20 5.50 7.50 4.76 6.35		Plant neight (cm)	cm)				0	1
a ₁ a ₂ 49.50 53.50 48.90 52.60 50.10 57.03 45.80 48.20 H 0.05) 0.60 4.66 6.80 4.70 6.20 5.50 7.50 4.20 4.90 an 4.76 6.35	Active tillering stage	s.			Floweri	Flowering stage		0: 12 2 3
49.50 53.50 48.90 52.60 50.10 57.03 45.80 48.20 48.57 52.83 H 0.29 0.5) 0.60 4.70 6.20 5.50 7.50 4.76 6.35 4.76 6.35	ซ้	a, Mean	a,	g.	a³	a,	a³	Mean
48.90 52.60 50.10 57.03 45.80 48.20 48.57 52.83 H 0.29 0.60 4.70 6.20 5.50 7.50 4.76 6.35 4.76 6.35	51 40	51.20 51.76	74.20	82.40	82.10	80.00	80.20	79.78
50.10 57.03 45.80 48.20 48.57 52.83 H 0.29 0.59 0.60 4.70 6.20 5.50 7.50 4.76 6.35 4.76 6.35	51.40	Ä	73.40	81.60	81.00	80.40	79.80	79.24
45.80 48.20 48.57 52.83 H 0.29 0.00 4.70 6.20 5.50 7.50 4.76 6.35 4.76 6.35	55.00		76.00	85.20	84.80	83.90	83.20	82.62
48.57 52.83 H 0.29 0.60 4.76 6.80 4.70 6.20 5.50 7.50 4.76 6.35 4.76 6.35	47.30	47.00 47.27	68.40	72.80	72.50	71.00	70.10	70.96
H 0.29 0.60 4.70 6.20 5.50 7.50 4.76 6.35	51.27		73.00	80.50	80.10	78.82	78.32	
(0.05) 0.29 (0.05) 0.60 4.66 6.80 4.70 6.20 5.50 7.50 4.20 4.90 an 4.76 6.35	d	Ha	H	Cattle		63	Ha	
(0.05) 0.60 4.66 6.80 4.70 6.20 5.50 7.50 4.20 4.90 an 4.76 6.35	0.33	990	0.2	-	0	0.24	0.48	8
4.66 6.80 4.70 6.20 5.50 7.50 4.20 4.90 4.76 6.35	190	1.35	0.43	3	O,	49	0.5	7
4.66 6.80 4.70 6.20 5.50 7.50 4.20 4.90 4.76 6.35	Number of tillers			Nur	nber of pr	Number of productive tillers	lers	
4.70 6.20 5.50 7.50 4.20 4.90 4.76 6.35	566		4.66	5.66	00.9	00'9	6,33	5.73
5.50 7.50 4.20 4.90 4.76 6.35	580		4.66	5.66	5.66	5.66	4.66	5.26
4.76 6.35	700		4.66	8.00	8.00	7.33	5.66	6.73
4.76 6.35	4.60	4.50 4.58	3.00	4.66	4.33	4.00	3.00	3.80
	5.76		4.25	00'9	00'9	5.75	4.91	
=======================================	æ	Ha	H			23	Ha	
0.16	0.18	0.36	0.5	55	0	0.62	1.24	4
CD (0.05) 0.32	0.36	67.0	1.12	2	-	36	2.5	23
H ₁ - Anilofos 0.4 kg ha ⁻¹ H ₂ - Butacl a ₁ - Control a ₂ - A. mic	H ₁ - Butachlor 1.25 kg ha ^{-t} a ₂ - A. microphylla	¹ H ₃ - Clomazone 0.3 kg ha ⁻¹ a ₃ - A. filculoides	one 0.3 kg h	a' H	- Control - TNAU hybrid	hybrid	a, - Rong	a, - Rong Ping hybrid

was applied (120:38: 38 kg ha⁻¹) to all the treatments.

The experimental soil was moderately alklaine in reaction (pH 8.0) and low in soluble salt content (EC < 0.45 dSm-1). The available nitrogen status was low with medium available P and K. To assess the sensitivity of Azolla species to rice herbicides, plant growth parameters, yield attributes and yield were recorded.

Results and Discussion

Sensitivity of Azolla to herbicides

Significant effect of herbicides on Azolla species on biomass (g) grown under water and soil medium were found out through screening study. Among the herbicides butachlor and clomazone performed well and were on par with each other followed by anilofs, 2,4-D and metsulfuran methyl (Table 1). Hence, three herbicides viz. anilofos, butachlor and clomazone were selected for pot culture study. Among the Azolla species all the four species performed well and are tolerant to

Table 3. Effect of herbicides and Azolla speices on yield and yield attributes

a ₁ a ₂ 20.60 22.66 20.36 22.16 20.43 25.26 17.16 18.46 19.64 22.14 H 0.37 0.76 95.00 111.66 95.00 145.00 93.33 91.66 95.25 117.08 H 4.49 96.25 117.08 H 4.49 90.9	Treatment			Panicle le	Panicle length (cm)					100 grain	100 grain weight (g)		
20.66 22.66 22.40 21.33 21.13 21.62 1.44 1.54 1.59 1.49 1.44 20.36 22.16 21.73 21.40 20.46 21.22 1.47 1.50 1.49 1.49 1.44 1.59 1.49 1.44 1.59 1.49 1.44 1.59 1.49 1.44 1.59 1.49 1.44 1.59 1.49 1.44 1.59 1.49 1.49 1.49 1.59 1.46 1.49 1.49 1.49 1.49 1.49 1.49 1.49 1.49	1100000	100	a,	ę	e ⁷		Mean	g g	g g	ę	a,	å	Mean
20.60 22.00 24.00 21.73 21.40 20.46 21.22 1.47 1.50 1.49 1.44 20.36 20.36 20.36 20.36 21.32 21.40 20.46 21.22 1.47 1.50 1.49 1.44 20.36 20.34 20.34 20.34 20.37 20.37 20.42 20.34 20.34 20.34 20.42 20.34 20.34 20.34 20.37 20.42 20.34 20.34 20.34 20.34 20.37 20.35 20.34 20.35 20.34 20				07.00	21 22	21 13	2162	144	1.54	1.52	1.48	1.45	1.48
20.36 22.16 21.73 21.40 20.46 21.22 144 1.64 1.59 1.55 20.43 25.26 23.23 23.23 23.00 18.14 1.64 1.59 1.56 17.16 18.46 18.50 18.36 18.23 18.14 1.64 1.59 1.56 17.16 18.46 21.08 20.67 1.71 1.32 1.46 21.08 20.67 1.71 1.32 1.46 21.08 20.67 1.71 1.32 1.46 1.39 1.36 1.46 1.90 1.46 1.40 1.40 1.40 1.40 1.40 1.40 1.40 1.40	н	20.60	22.66	77.40	21.33	21.13	20.12	, ,	5	1.40	144	4	1.47
20.43 25.26 23.23 23.28 22.86 23.00 144 164 1.59 1.50 1.56 18.46 18.50 18.35 18.23 18.14 0.92 14.1 1.39 1.36 1.36 18.23 18.14 0.92 14.1 1.39 1.36 1.36 18.23 18.14 0.92 14.1 1.39 1.36 1.46 19.64 22.14 21.46 21.08 20.67 1.71 0.02 0.02 0.02 0.03 0.76 0.85 0.08 0.08 0.04 0.00 0.04 0.00 0.00 0.00		35 00	22 16	21.73	21.40	20.46	21.77	1.4/	3	1.1		2	1.55
17.16 18.46 18.50 18.35 18.31 18.14 0.92 1.41 1.39 1.36 1.36 1.36 1.46 1.30 1.36 1.46 1.30 1.36 1.46 1.30 1.35 1.46 1.32 1.52 1.50 1.46 1.46 1.30 1.46 1.30 1.46 1.30 1.46 1.30 1.46 1.30 1	Ъ	20.00	1000	20.00	22 23	22 86	23 00	4	16	1.59	8	1.32	0.1
17.16 18.46 18.50 18.25 19.14 1.32 1.52 1.50 1.46 19.64 21.08 20.67 1.41 1.32 1.52 1.50 1.46 19.64 20.14 21.08 20.67 1.71 0.02 0.02 0.02 0.02 0.02 0.05 0.	Н	20.43	07.67	77.77	43.63	20.93	10 14	000	141	1 39	1.36	1.33	1.28
19.64 22.14 21.46 21.08 20.67 1.32 1.	ת	17.16	18.46	18.50	18.36	18.23	10.14	200	100	1 50	1.46	1.43	
H	Mean	19 61	22,14	21.46	21.08	20.67		1.32	727	2	24.4	7.17	
H a Had 0.02 0.02 0.37 0.42 0.84 0.02 0.05 0.76 0.85 1.71 0.04 0.02 0.05 0.76 0.85 1.71 0.04 0.02 0.05 0.76 0.85 0.08 0.04 0.09 0.00 0.76 1.20 0.113.33 108.33 105.00 108.66 40.00 53.33 51.66 50.00 95.00 111.66 103.33 105.00 124.66 40.00 51.66 50.00 50.00 100.00 145.00 128.33 125.00 124.66 41.66 55.00 55.00 55.00 55.00 55.00 50.00 96.25 117.08 110.83 104.58 103.33 36.24 49.58 48.75 47.50 96.25 117.08 110.83 104.58 103.33 10.05 2.99 3.35 449 5.02 10.17 20.34 6.06	Mican					1		#		(H)	co	-	Ia
0.37 0.42 0.84 0.02 0.02 0.02 0.76 0.76 0.85 1.71 0.04 0.02 0.02 0.76 0.76 0.85 1.71 0.04 0.05 0.02 96.66 120.00 113.33 108.33 105.00 108.66 40.00 53.33 51.66 50.00 95.00 111.66 113.33 108.33 105.00 124.66 40.00 51.66 50.00 50.00 95.00 111.66 111.66 103.33 105.00 124.66 41.66 55.00 50.00 50.00 95.25 117.08 110.83 104.58 103.33 38.33 38.33 38.33 36.66 449 5.02 10.05 10.05 2.99 3.35 47.50 509 10.17 20.34 49.58 48.75 47.50 909 10.17 20.34 40.58 8.75 6.08 909 10.17 20.34 </td <td></td> <td>-</td> <td>Œ</td> <td></td> <td>-</td> <td>4</td> <td>13</td> <td></td> <td>8</td> <td>•</td> <td></td> <td>•</td> <td>90</td>		-	Œ		-	4	13		8	•		•	90
Straw yield (g/pot) 96.66 120.00 113.33 105.00 108.66 40.00 53.33 51.66 50.00 95.00 111.66 111.66 103.33 105.00 124.66 40.00 51.65 50.00 50.00 95.00 111.66 111.66 103.33 103.33 105.00 40.00 51.65 50.00 50.00 96.25 117.08 110.83 104.58 103.33 36.24 49.58 48.75 47.50 H	SEd	0 0	37	ŏ ö	85	0 H	21.	88	2 2	00	70°.	00	01:
96.66 120.00 113.33 108.33 105.00 108.66 40.00 53.33 51.66 50.00 5	(co.o)			Straw vie	(g/pot)					Grain yi	eld (g/pot)		
96.66 120.00 113.33 103.33 105.00 40.00 51.66 50.00 50.00 55.33 105.33 105.00 145.00 124.66 80.00 87.33 23.33 38.33 36.66 55.00 55.33 38.33 36.66 55.00 55.33 100.00 81.66 80.00 87.33 25.30 38.33 38.33 36.66 55.00 55.33 117.08 110.83 104.58 103.33 104.58 103.33 104.58 103.33 100.5 100.5	,		9.7		10033		108 66	40.00	53.33	51.66	50.00	50.00	19.00
95.00 111.66 111.66 103.33 103.33 103.33 103.33 103.33 103.33 103.33 103.33 103.33 104.58 104.58 103.33 104.58 104.58 103.33 104.58 104.58 103.33 104.58 104.58 103.33 104.58 103.33 104.58 104.58 103.33 104.58 103.33 104.58 103.33 104.58 103.33 104.58 104.58 103.33 104.58 104.58 104.58 100.5 10.05 10	H.	99.96	120.00	113.33	108:33	103.00	105.00	00.05	51.66	20.00	50.00	48.33	48.00
100.00 145.00 128.33 125.00 12	щ	95.00	111.66	111.66	103.33	103.33	103.00	41.66	55.00	55.00	53.33	53.33	51.66
93.33 91.66 90.00 81.66 80.00 87.33 42.30 36.24 49.58 48.75 47.50 96.25 117.08 110.83 104.58 103.33 36.24 49.58 48.75 47.50 4.49 5.02 10.05 20.34 6.06 6.06 6.78 05) 9.09 10.17 20.34 H ₁ - Clomazone 0.3 kg ha ⁻¹ H ₄ - Control a ₂ - A. microphylla a ₃ - A. filculoides a ₄ - TNAU hybrid*	H,	100.00	145.00	128.33	125.00	D.C.	02.4.00	20.14	30.22	38 33	36.66	28.33	32.99
96.25 117.08 110.83 104.58 103.33 36.24 49.30 46.73 71.30 H a a Ha A A 3.35 4.49 5.02 10.05 2.99 6.78 05) 9.09 10.17 20.34 6.06 6.06 6.78 milofos 0.4 kg ha ⁻¹ H ₂ - Butachlor 1.25 kg ha ⁻¹ H ₃ - Clomazone 0.3 kg ha ⁻¹ H ₄ - Control a ₂ - A. microphylla a ₃ - A. filculoides a ₄ - TNAU hybrid*	'n	93.33	91.66	80.00	81.66	80.00	87.33	25.50	10.00	10.75	05 CV	45.00	
H a a Ha Ha 3.35 4.49 5.02 10.05 2.99 5.78 6.06 6.06 6.78 milofos 0.4 kg ha ⁻¹ H ₂ - Butachlor 1.25 kg ha ⁻¹ H ₃ - Clomazone 0.3 kg ha ⁻¹ H ₄ - Control a ₂ - A. microphylla a ₃ - A. filculoides a ₄ - TNAU hybrid*	Mann	56.76	117.08	110.83	104.58	103.33		36.24	49.38	40.13	00-14	2000	
H a 5.02 10.05 2.99 3.35 6.78 5.09 10.17 20.34 6.06 6.06 6.78 6.78 9.09 10.17 20.34 H ₃ - Clomazone 0.3 kg ha ⁻¹ H ₄ - Control a ₃ - A. filculoides a ₄ - TNAU hybrid*	Mean					100	i i		н		c		Ha
4.49 5.02 10.05 6.78 6.78 6.78 6.06 9.09 10.17 20.34 6.06 6.06 6.78 6.78 6.78 6.78 6.78 6.78 6.78 6.7			I						8	1001	335		6.70
ofos 0.4 kg ha ⁻¹ H ₂ - Butachlor 1.25 kg ha ⁻¹ H ₃ - Clomazone 0.3 kg ha ⁻¹ H ₄ - Control a ₂ - A. microphylla a ₃ - A. filculoides a ₄ - TNAU hybrid*	SEd	4.0	60	2. 2.	20.	A 50	0.34	40	8 8		6.78		13.56
a ₂ - A. microphylla a ₃ - A. Jucummes	H, - Anilofe	os 0.4 kg l		- Butachle	or 1.25 kg	, ha-1	H, - Cloma	zone 0.3 kg		1 1	ol hybrid"	a, - Ro	ng Ping hybric
	a, - Control		13	- A. micro	phytia		a, - A. Juci	e de la contraction de la cont	5			,	

herbicides without any ill effects on its growth. So all the species of Azolla were chosen for pot culture experiment. The results of screening study showed that in higher dose of herbicides on the four Azolla species were able to survive but the growth was good only in recommended dose. Hence, recommended doses were selected for pot culture experiment

The results of growth and yield para meters due to the effect of combination of herbicides with Azoll are presented in Table 2 and 3.

Effect on plant growt characters

Plant height (cm)

Significant diffe rences in plant heigh at different stages wer observed due to variou treatments. At tillerin stage among the herb cides tried, clomazor at 0.3 kg har recorde the highest plant heig (54.5 cm) followed t anilofos at 0.4 kg ha (51.7 cm). Regardin the Azolla sp. the highe height plant observed in A. micr phylla and was four to be on par wi A.filculoites. The inte action effect was al significant among t treatments. The high plant height was obse ved in (clomazone

A. microphylla) (57.0 cm) and this was on par with (clomazone + A. filculoites). The lowest plant height was observed in absolute control (48.6 cm). Similar results were observed in flowering stage:

Number of tillers

On perusal of the data, the number of tillers was in the range of 4.2 to 7.3. The maximum number of tillers were observed in clomazone applied pot (6.9) and among the Azolla species, A. microphylla recorded the highest number of tillers (6.3). The interaction effect was found to be non-significant. At flowering stage, significant effect due to interaction was observed among herbicides and Azolla species. The treatment which received clomazone + A. microphylla recorded the highest number of tillers (12.0) and the lowest was found in absolute ontrol (7.0).

The data on productive tillers showed significant effect of treatments. The highest productive tillers were observed (6.7) in clomazone at 0.3 kg ha⁻¹ followed by (5.7) anilofos at 0.4 kg ha⁻¹. Among the Azolla species, the highest number of productive tillers were observed in A. microphylla (6.0). The interaction effect was non-significant among the herbicides and Azolla.

Yield Attributes

The various treatments significantly influenced the yield attributes (Table 3). The nighest panicle length and test weight were recorded in clomazone applied pots (23.0 cm, 1.55 g). Among the Azolla species, Azolla microphylla recorded the highest panicle length and test weight (22.1 cm, 1.52 g). The highest panicle length and test weight was observed in clomazone + A. microphylla followed by clomazone + A. filiculoides.

Yield

The grain and straw yields ranged from 23.3 to 55.0 g pot⁻¹ and from 93 to 145 g pot⁻¹ respectively. The lowest yield was observed in absolute control. The maximum grain and

straw yield was observed in clomazone + A. microphylla (55.0 g). The concomitant use of herbicides + Azolla may augment the grain yield by protecting the crop from weeds and probably by increasing the N fixation by Azolla species. The results of Azolla inoculation improving rice yields are in consonance with the reports of Nazeer and Prasad (1984) and Singh and Singh (1995). Among the herbicides tried, clomazone at 0.3 kg ha⁻¹ increased the grain yield.

References

- Anon, (2001). Reduced food grains output in 2000-2001. In: Economic Survey, 2000-2001. India Grains, p.9.
- Brar, L.S. and Walia, U.S. (2001). Influence of nitrogen levels and plant densities on the growth and development of weeds in transplanted rice. *Indian J. Weed Sci.* 33: 127-131.
- Britto, A.J.D.E. and Seethalakshmi, C. (2002). The effect of 2,4-D on the growth of Azolla microphylla and Azolla filiculoides. Weed abstracts, 51: p.273.
- Ghosh, A. and Moorthy, B.T.S. (1998). Weed management deserves more attention in rainfed lowland cultivation. Ind. Fmg. 48: 15-18.
- Kathiresan, R.M., Ramah, K. and Sivakumar, C. (2002). Integration of Azolla, fish and herbicides for rice weed management. Weed Abstracts, 51: 476.
- Nazeer, M. and Prasad, N.N (1984). Effect of Azolla application on the yield and soil properties. Phykos, 23: 269-272.
- Singh, D.P. and Singh, P.K. (1995). Influence of rate and time of Azolla caroliniana inoculation on its growth and nitrogen fixation and yield of rice. Indian J. Agric. Sci. 65: 10-16.
- Swaminathan, M.S. (1998). Issues and challenges in sustainable increased rice production and the role of rice in human nutrition in the World. In: Intl. Rice Commu. 98/2-2, Cairo, Egypt p.23.

(Received: November 2002; Revised: September 2003)