Physiological indices to yield variation under rice-weed competition in direct seeded lowland condition

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ABSTRACT

The efficacy of the six were evaluated on yield of rice cultivar Govind in direct seeded lowland rice ecosystem. The study revealed that hand weeding was superior to the chemical weed control for all the growth and yield attributes, reflecting higher grain yield of 3245kg ha^{-1} in clayey loam soil during rainy season because of frequent elimination of weeds that resulted in the reduced weed competition. In direct seeded lowland rice, herbicide oxyfluorfen @ 0.24kg/ha can effectively control weeds of rice such as grasses, sedges and broadleaved weeds if applied as one pre emergence at 1 days after sowing (DAS) . Even though some phytotoxicity effect was noticed on rice seedlings pertaining to reduction in plant height and total number of tillers but the seedlings recovered and resulted in higher grain yield of 2987.5kg ha^{-1}and total dry matter of 227.9 g m^{-2} but lower than hand weeding practice. The lower yield of 7.9% ha^{-1} by oxyfluorfen application might be due to weed competition and might have resulted from the phytotoxicity and resultant shock experienced by the crop due to phytotoxicity during the seedling stage. On the other hand, application of herbicide significantly increased the leaf area index (LAI), relative growth rate (RGR), net assimilation rate (NAR) and crop growth rate (CGR) as well as increased carbohydrate and starch content over unweeded check.

Key words: *CGR; LAI;NAR; RGR; rice-weed competition*

Weeds are a major cause of reduction in crop yields in rice. Though the problem is less severe in transplanted rice, severe crop losses occur in direct seeded rice. One estimate at IRRI showed that the weed growth in unweeded plots reduced yield by 34 percent in transplanted rice, 45 per cent in direct seeded rainfed lowland rice and 67 per cent in upland rice (De Datta 1981).

A mixed population of grassy weeds, sedges as well as non-grassy broadleaf and aquatic weeds is dominating rice field depending on prevailing climatic conditions, soil types, water management, crop establishment practices, weed seed bank in soil and cropping system adopted in different rice ecologies. Hand weeding is the traditional weed control measure in rice. However, due to high labour cost, non availability of labour and time taken for manual removal,farmers are forced to option for cheaper alternative of chemical weed control. Identification of growth physiological indices in analysis of factors affecting yield and its components has a great importance and its stability to determine the dry matter production which is a criterion of yield components and in this regard leaf area index, total dry weight (TDW) and leaf dry weight (LDW) should be measured in periodic intervals during the growing season Gardner *et al.* 1985. In addition to the above indices, crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area duration (LAD), leaf area rate (LAR), Leaf weight rate (LWR) and specific leaf area rate (SAR), chlorophyll content and their influence on dry matter production and grain yield are important indices which often used for evaluation of plant productivity capability and environmental efficiency Anzoua KG *et al.* 2010. In view of this an experiment was conducted to determine the physio-morphological attributes in relation to yield variation under rice-weed competition in direct seeded lowland condition.

MATERIALS AND METHODS

The field trial was conducted during *Kharif*, 2015 at Central Farm, Orissa University of agriculture & Technology, situated at 85º 52' E longitude and 20º 15' N latitude with a elevation of 25.5 meters above sea level. The soil of the experimental site was clayey loam with acidic pH of 5.4, organic carbon content of 0.56%, available N 152 kg/ha, available P 16.3 kg/ha and available K 89.6 kg/ha. The rice variety Govind was used. The experiment was laid out by following Randomized Block Design with three replications and eight treatments. Plot size was 30 m2. The treatments consisted of Pretilachlor 50EC @0.75 kg/ha (pre-emergence@1DAS), Butachlor 50 EC @1 kg/ha (pre-emergence at 1DAS), Pendimethalin 30 EC @1kg/ha (pre-emergence at 1DAS), Propanil 35 EC@3kg/ha (post-emergence at 10DAS), Oxyfluorfen 23.5 EC@0.24kg/ha (pre-emergence at 1DAS), Cyhalofop-butyl, 110 EC @ 0.08kg/ha (post-emergence@10 DAS), hand weeding at 15,30,45 days after sowing and unweeded control.

Destructive sampling was done at thirty days interval by uprooting five hills per plot. Leaf area was measured by using LI-3100 leaf area meter (LICOR-Lincoln, Nebraska, USA). Dry weight of the plant parts were recorded by subjecting the sample at 70°C temperature in hot air oven till constant weight was obtained and dry weight was expressed in g m^{-2}. Physiological growth parameters were calculated by using standard formulae and the acetone method was used for determining the chlorophyll content of leaves. Phytotoxicity was calculated as follows:

$$\text{Phytoxicity (\%)} = \frac{\text{Chlorophyll in control - chlorophyll in treatments}}{\text{Chlorophyll in control}} \times 100$$

Plant height, weed count as well as dry weight production of weeds were recorded at 30, 60and 90 days after sowing (DAS). Plant height, total tillers per hill, productive tillers per hill, grain yield and straw yield were recorded at harvest. Yield attributes like no. of panicle m^{-2}, panicle length, total number of spikelets per panicle, test weight, filled grain percentage, yield and harvest index were recorded at maturity.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads

Microbial studies

Results on microbial population after application of herbicide revealed that the microbial activity was reduced within 7 days of application and after that their population was increased and maintained. Reduction on microbial population at the early stages of crop growth hampered the primary metabolic activity as a result decrease in physiological attributes observed.

Weed Flora

The weed flora of the experimental fields like Echinochloa colona and Echinochloa crus-galli were mostly prevalent in the plots followed by *Leptochloa chinensis* and *Digitaria sanguinalis* among grassy weeds. *Commelina benghalensis* and *Cleome viscosa* as broad leafweeds found in experimental plots . *Cyperus iria*, *Cyperus difformis* also found as sedge in experimental field .

Effect on weeds

The results indicated that all the herbicide treatments brought significant reduction in the weed population and weed dry matter production compared to the unweeded control (Table 1). Weed count as well as drymatter production recorded at 30, 60 and 90days after sowing resulted similar trend. The percentage of decrease in weed population of weed free plots as compared to control was 96.1% and 97.2% at 60DAS and at harvest respectively. Among the herbicides, oxyfluorfen excelled over their counter parts in respect of suppression of weed.

Phytotoxicity to rice

The phytoxicity of herbicides on rice plant was determined through pigment analysis and by visual observation (toxicity rating scale 0-10 scale used where 0-no injury, 10-burning or death of the seedling). It was found that herbicides were toxic at early growth stage

Table1. Grain yield and yield attributes

	Treatments`	Grain yield (kg/ha)	Harvest index(%)	Test weight(g)	Weed index (%)	Phytotoxicity in rice (on pigment basis)	
						90DAS	120DAS
T_1	Pretilachlor	2362.5	43.0	21.94			
		(27.2)	(4.9)	(3.43)	27.2	11.11	10.34
T_2	Butachlor	2010.0	41.5	21.72			
		(38.05)	(8.1)	(4.40)	38.1	2.78	10.34
T_3	Pendimethalin	2680.5	43.7	22.01			
		(17.4)	(3.33)	(3.12)	17.4	8.33	3.45
T_4	Propanil	2705.0	43.9	22.2			
		(16.6)	(2.9)	(2.3)	16.7	22.22	24.14
T_5	Oxyfluorfen	2987.5	44.6	22.42			
		(7.9)	(1.33)	(1.32)	7.94	-5.56	-1.38
T_6	Cyhalofop-butyl,1	1785.0	40.5	21.39			
		(45.00)	(10.4)	(5.9)	44.99	16.67	27.59
T_7	Weed free	3245.0	45.2	22.72	0		
T_8	Unweeded	821.5	36.9	21.01			
	control	(74.68)	(18.36)	(7.53)			
	SE(m)+	156.63	2.40	0.78	3.53		
	LSD(5%)	475.05	7.29	2.35	7.59		
	CV(%)	11.67	9.82	7.05	9.99		

Figures in the parentheses indicates % decrease over the weed free observation

of rice plant and plants recovered gradually. Phytotoxicity symptoms like failure of germination, vein clearing, yellowing of leaf, wilting, leaf tip burning, reduction in plant population *etc* were examined and found that all the herbicides tried were phytotoxic at all the rates of application. But pre-emergence application of oxyfluorfen resulted in yellowing and drying of leaves in rice seedlings and the intensity of phytotoxicity was least among the herbicides used. However, the new leaves emerged were free from any damage and the rice seedlings recovered from the phytotoxicity after 15 days of spraying. Moorthy and Manna (1988) reported that Oxyfluorfen @ 0.1 kg/ha caused phytotoxicity to rice. Pillai *et al*. 1983 also reported slight toxicity to rice when Oxyfluorfen was applied@ 0.2 kg/ha six days after transplanting.

Physiological indices of rice

Leaf area index (LAI) increased up to 90 DAS beyond which declined sharply, significant variation was observed in LAI among the treatments at all the growth stages of (Table 2). Maximum LAI of 5.20 was recorded for hand weeding followed by oxyfluorfen (5.0) and minimum of 2.81 was noted for unweeded control at 90 DAS. The decrease in the leaf area index towards maturity was due to less number of green leaves as a result of accelerated senescence of matured leaves.

Leaf area duration (LAD) varied among the treatments (Table 3). Among the treatments maximum LAD was recorded in hand weeding plots followed by oxyfluorfen treatment. Higher LAD due to suppression of weeds may be one of the reason for higher photosynthetic rate and dry matter production. Significant positive association between LAD and yield was reported by Kastura *et al.* (2007).

Leaf area ratio (LAR) an indices of leafiness of plant showed significant difference among the treatments. It increased up to 90 DAS and thereafter decreased at maturity. Similar results were also reported by Park *et al.* (2004). Maximum LAR was recorded in weed free hand weeding(201.7 $cm^2\ g^{-1}$) at 90 DAS and minimum LAR was recorded in unweeded control(103.67 $cm^2\ g^{-1}$).

Table2. Physiological parameters of plant height, total tiller no., LAI, and starch percentage.

Treatments	Plant height(cm)			Total tiller no. per m²			LAI			Starch
	60DAS	90DAS	120DAS	60DAS	90DAS	120DAS	60DAS	90DAS	120DAS	(%)
T1	Pretilachlor	70.5(9.50)	113.3(5.43)	120.7(12.5)	332.8(9.9)	489.2(22.4)	465.2(23.3)	2.40(1.23)	4.24(18.46)2.80(24.3)	
71.66	T2	Butachlor	70.8(9.11)	110.4(7.85)	125.2(9.2)	344.8(6.7)	488(22.6)	464(23.5)	2.09(13.99)	
4.21(19.04)	3.00(18.9)	71.38	T3	Pendimethalin74.8(3.98)		116.0(3.17)	134.1(2.8)	345.5(6.5)	513.2(18.6)	
489.2(19.4)	2.20(9.47)	4.33(17.63)	2.63(28.9)	72.14	T4	Propanil	72.1(7.45)	111.8(6.68)	124.1(10.0)336.9(8.8)	
566.68(10.1)	542.68(10.5)	2.11(13.17)	4.90(5.77)	3.61(2.4)	72.51	T5	Oxyfluorfen	73.9(5.13)	115.0(4.01)136.5(1.0)	
353.5(4.3)	613.32(2.8)	589.32(2.9)	2.42(0.41)	5.00(3.85)	3.65(1.4)	73.75	T6	Cyhalofop-butyl,1		
70.0(10.14)	112.7(5.93)	128.8(6.6)	332.0(10.1)	464(26.4)	440(27.5)	2.16(11.11)	3.94(24.23)	2.08(43.8)	71.05	T7
Weed free	77.9	119.8	137.9	369.5	630.68	606.68	2.43	5.20	3.70	76.01
T8 Unweeded control	66.8(14.25)	94.6(21.04)	111.2(19.4)	299.5(18.9)	441.32(30.0)	417.32(31.2)	1.61(33.74)	2.81(45.96)	1.71(53.8)	
66.89	SE(m)±	4.1	6.3	5.0	3.3	4.7	15.05	0.17	0.34	0.23
LSD(5%)	12.4	19.0	15.2	10.0	14.3	45.63	0.51	1.53	0.69	

Figures in the parentheses indicates % decrease over the weed free observation

Crop growth rate (CGR) differed significantly among the treatments. The highest CGR of 9.57 g m^{-2} day^{-1} was recorded for hand weeding and minimum CGR was recorded in unweeded control plots. Similar finding were also reported by Erfani and Nasiri (2000). Crop growth rate (CGR) increased at early stages in most of the treatments after that it was decreased. The higher value of CGR in weed free and oxyfluorfen treated plots over unweeded control correlated with grain yield in the respective plots. The increase in CGR was due to increased leaf area index values and light interception thereby increased photosynthetic rate and dry matter production. After reaching the maximum CGR it decreased till maturity due to ageing of leaves and leaf shedding.

Relative Growth Rate (RGR) The data revealed that RGR value of weed free (27g/m^2/day) and oxyfluorfen treatment (26g/m^2/day) were statistically at par and higher than unweeded control (21g/m^2/day). Relative growth rate (RGR) decreased with the age of crop. Similar decrease of RGR with the age of crop was reported by Chandrasekhar *et al.* (2001). The reason of this decrease with the age of plant was due to senescence of leaves and decrease in metabolic activities (Nicknejad *et al.* 2009).

Net Assimilation Rate (NAR) Among the treatments maximum net assimilation rate (NAR) was recorded in weed free (2.5 g $m^{-2}day^{-1}$) between 60-90 DAS which was found at par with pendimethalin, propanil and oxyfluorfen but significantly higher than rest of the treatments and minimum NAR was recorded by the unweeded control. Reduction in NAR could be attributed to less leaf area and shortage of other growth factors (nutrient, space, water etc.) and method of weed suppression.

Hand weed free plots recorded highest LAI as well as highest CGR among the treatments followed by oxyfluorfen. This clearly indicated that production of maximum dry matter by weedfree plot was due to its higher CGR, NAR, RGR and LAD.

Dry Matter Production (DMP) and grain yield

Variation in total biomass production, harvest index and 1000 grain weight was indicated higher value in both hand weeding (718.5g/m^2, 45.2%, 22.72g) and oxyfluorfen (669.1g/m², 44.6%, 22.42 g) resulted in

Table3. Physiological parameters of LAD,NAR,CGR,RGR,TDM,LAR,Carbohydrate and Nitrogen content

Treatments Nit- 90)DAS	LAD ohydrate	NAR rogen	CGR (60-	CGR (60-	RGR (60-90)DAS	RGR (90-90)DAS	TDM(g per m2) (60-90)DAS	TDM(g per m2) (90-120)DAS	TDM(g per m2) 60DAS 90)DAS	LAR 90DAS 120)DAS	carb- 120DAS (60-
(%)		(%)	T_1	Pretilachlor	38.1	2.1	6.35	5.68	24.9	12	189 379.6
550 113.7	15.94	1.12			(36.82)	(16)	(33.65)	(12.9)	(7.8)	(20)	(19.88)
(27.4)	(23.45)	(43.63)				T_2	Butachlor	42.7	1.7	5.04	5.41 24.6 11.4
171 322.2	484.5	112.8	15.92	1.04			(29.19)	(32)	(47.33)	(17.02)	(8.9) (24)
(27.5)	(38.38)	(32.56)	(44.1)				T_3	Pendimethalin	43.5	2.2	7.88 5.94 25.2
12.6 199.4	435.8	614	116.6	20.28	1.26			(27.86)	(12)	(17.66)	(8.9) (6.7) (16)
(15.47)	(16.65)	(14.54)	(42.2)				T_4	Propanil	58.4	2.3	7.89 5.98 25.6
13 200.5	437.2	616.6	127.5	16.74	1.3			(3.15)	(8)	(17.55)	(8.3) (5.2)
(13.33)	(15)	(16.38)	(14.18)	(36.8)				T_5	Oxyfluorfen	53.7	2.4 8.69 6.02
26 14	227.9	488.5	669.1	139.6	23.94	1.43			(10.95)	(4)	(9.2) (7.7)
(3.70)	(6.67)	(3.39)	(6.57)	(6.87)	(30.8)				T_6	Cyhalofop-	35.3 1.5 4.38
5.29 24.5	11	150	281.5	440.2	107.3	15.58	0.9		butyl,1	(41.46)	(40) (54.23)
(18.9)	(9.26)	(26.67)	(36.41)	(46.1)	(38.73)	(46.80)				T_7	Weed free 60.3
2.5 9.57	6.52	27	15	235.9	522.9	718.5	201.7	25.94	1.52	T_8	Unweeded 19.3
0.7 3.00	1.43	21	7	90	140	222.8	103.6	14.56	0.82		control
(67.99)	(72)	(68.65)	(78.1)	(22.22)	(53.33)	(61.84)	(73.22)	(68.99)	(48.64)		
SE(m)±	2.80	0.13	0.48	0.23	1.98	1.03	9.4	7.0	10.6	2.87	
LSD(5%)	8.50	0.38	1.45	0.69	6.01	3.11	28.6	21.3	32.1	8.69	
CV(%)	11.06	11.30	12.52	7.49	13.80	14.82	7.5	5.4	5.6	3.88	

Figures in the parentheses indicates % decrease over the weed free observation

Table 4. Correlation of grain yield with different physiological attributes in rice-weed competition

	Grain Yield	Harvest Index	1000 grain wt.	Weed Index	LAI	LAD	NAR	CGR	RGR	TDM	LAR
yield	1.000										
Harvest Index	0.906**	1.000									
1000 grain wt.	0.957**	0.818*	1.000								
Weed Index	-0.996**	-0.900**	-0.965**	1.000							
LAI	0.965**	0.797*	0.931**	-0.971**	1.000						
LAD	0.932**	0.755*	0.898**	-0.934**	0.980**	1.000					
NAR	0.988**	0.903**	0.936**	-0.989**	0.963**	0.917**	1.000				
CGR	0.969**	0.886*	0.968**	-0.976**	0.926**	0.910**	0.951**	1.000			
RGR	0.968**	0.829*	0.906**	-0.965**	0.974**	0.928**	0.957**	0.893**	1.000		
TDM	0.650	0.605	0.622	-0.668	0.695	0.762*	0.584	0.687	0.651	1.000	
LAR	0.717*	0.475	0.817*	-0.712*	0.707*	0.724*	0.625	0.757*	0.690	0.602	1.000

(*),** Significant at 5% and 1% level of significance.

higher yields, which were at par statistically but superior to rest of the treatments. Azad *et al*. (1990) reported that application of oxyfluorfen granules controlled all types of weeds from germination stage, gave the lowest dry weight of weeds, highest number of panicles per square meter and the highest yields. The TDM increased with the age of crop, irrespective of treatments. Grain yield exhibited highly significant positive correlation with most of the physiological parameter except weed index which had negative relationship with yield (Table 4). Yield as compared to other combinations which might be attributed to increase in growth parameters besides increase in physiological activities with high LAI, LAD, CGR, NAR and RGR, and finally the highest DMP. This is in accordance with the findings of Thakur and Patel (1998) who reported that dry matter production, LAI, LAD, CGR, NAR and RGR are ultimately reflected in higher grain yield.

The carbohydrate accumulation of the rice plant found closely associated with nitrogen nutrition. According to Takahashi *et al.* (2001), a high nitrogen responsive variety tends to accumulate more starch before flowering, particularly when subjected to high nitrogen levels, than a low nitrogen responsive variety. The data for carbohydrate content revealed that weed free (hand weeding) plant contained maximum (25.94%) carbohydrate followed by oxyfluorfen (23.94%) which was 78.15% and 64.42% high over unweeded control respectively. Among the weedicides applied oxyfluorfen performed better in increasing carbohydrate content of rice grain.

Generally starch content may be controlled by a balance between "production" and "consumption", data on starch content in rice grain revealed that hand weeded plant contained maximum (76.01%) starch in grain followed by oxyfluorfen (73.75%) which was 13.63% and 10.25% higher over unweeded control where it was minimum (66.89%). If the production exceeds the consumption, starch may be accumulated as a reserve carbohydrate. As the starch content of the rice plants tends to be low under low light intensities (Tanka *et al.*1964), it can be expected that the starch content will decrease when the mutual shading becomes serious.

Among the treatments, weed free plant contain maximum (1.52%) nitrogen content in shoot followed by oxyfluorfen (1.43%) which was 85.36% and 74.39% high over unweeded control (0.82%). Nitrogen consumes some carbohydrate for synthesis of amino acids or proteins and the formation of new organs such as leaf blade or leaf sheath requires much carbohydrate for cellulose, hemicellulose, lignin, *etc*.

From the above experiment it was concluded that hand weeding was superior to the chemical weed control for increasing all the growth and yield attributes and to achieve higher grain yield but pre-emergence application of Oxyfluorfen @ 0.24 kg/ha can also be considered effective in controlling the rice-weed competition and increase grain yield in direct seeded low land ecosystem.

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