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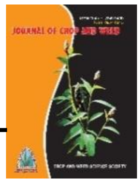

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Chemical management of weed in direct seeded rice (*Oryza sativa* L.)

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ABSTRACT

Over the course of two consecutive years, field experiments were carried out at the 'C' block unit farm of Bidhan Chandra Krishi Viswavidyalaya, located in Kalyani, West Bengal, India, during kharif season of 2017 and 2018. The objective was to devise an efficient and eco-friendly chemical weed management approach using novel herbicidal compounds for rice cultivation. The experiment followed a complretely randomized block design comprising eight different treatments: T1: Oxyfluorfen 23.5%EC @ 650 ml ha-1, T2: Oxyfluorfen 23.5%EC @ 1000 ml ha-1, T3: Butachlor 50%EC @ 1.25 kg ha-1, T4: Anilophos 30%EC @ 0.4 kg ha-1, T5: Pyrazosulfuron ethyl 10%WP @ 150 g ha-1, T6: Untreated control (weedy check), T7: Untreated control (weed free check), and T8: Oxyfluorfen 23.5%EC @ 2000 ml ha-1 for phytotoxicity study, in three replications. Yellow sarson was sown as follow up crop after direct seeded kharif rice to investigate the residual effects of various weed control methods implemented during the rice cultivation. Experimental result indicated that the highest rice grain yield was achieved from T7 treatment i.e., weed free check and lowest from T6 treatment i.e., weedy check plot. It was also found that impacts of various herbicides on rice grain yield were significant over T6. Among the chemical treatment, T2 (Oxyfluorfen 23.5% EC @ 1000 ml ha-1) recorded with maximum rice grain yield. The lowest weed dry weight and weed density were recorded for T7 (weed free check) treatment followed by Oxyfluorfen 23.5%EC @ 2000 ml ha-1 (T8) treated plot at all stages of observations taken. Application of Oxyfluorfen 23.5%EC @ 2000 ml ha-1 observed slightly better weed control efficiency in rice than applied @ 1000 ml ha-1, but reduction in grain yield was found at greater concentration of Oxyfluorfen due to adverse impact on plant growth which reflected in yield contributing characters and yield. Maximum microbial population (bacteria, fungi and actinomycetes) was found at T7 treatment at all stages of experiment, though it turned non-significant at 60 DAA. Effect of various chemical herbicides applied in kharif rice was non-significant on germination, growth and yield of yellow sarson. No phytotoxic effect was found both on rice and yellow sarson due to application of chemical herbicides even in higher doses.

***Keywords*: Chemical weed management, microbial population, phytotoxicity study and rice grain yield**

Globally, the most significant and extensively grown cereal crop is rice (*Oryza sativa* L.), consuming as an essential and principal sustenance by exceeding 60% of the global residents. In India, rice is grown all year round in various regions of the province which spreads over 45 M ha with a yield of around 118 Mt of husked rice and average productivity of 3.96 t ha^{-1} (FAOSTAT, 2020). Various biotic and abiotic stresses are the limitations to accomplish potential rice yields. Infestation of weeds in crop fields is the prime stress factor among the biotic factor causes. Weeds are most extensive biological restraints to crop production as it creates interference and inconvenience to agricultural operations, hampers crop yield considerably a well as reduces the standard of the harvest. Yield losses in rice because of weed is one of the most important reasons among others (Paul *et al*., 2014). The types of weed vegetation and their severity in rice differs evidently with the cultivation practice of rice which mainly depends on the moisture content of the field; varying from dry to deep flooded. Similar necessities of rice and rice associated weeds for advancement causes competition for resources like nutrients, moisture, light, space etc.

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High adaptive nature and speedy growth rate of weeds subjugate the crop habitat as a result of depletion of yield potential occurs (Parameswari and Srinivas, 2017). According to Mahajan *et al.* (2009), reduction in crop yield may go as far as 57% in transplanted rice field while 82% in broadcasting seed technique due to uncontrolled weed growth. Crop weed competition causes the average rice yield loss in the range between 40-60% that might increase prior to 94-96% because of excessive growth of weed (Chauhan and Johnson, 2011). The challenges of producing rice differ from place to place because of growing in widely varying environment like rainfed uplands, irrigated uplands, rainfed lowlands etc. (Choudhary and Suri, 2014, and Kaur *et al*., 2015). Weed management in rice is challenging, complicated, expensive and systematic. Herbicide is the preferred method of controlling weed and it is the first and apparently the last line of defence. The objective was to devise an efficient and eco-friendly chemical weed management approach using novel herbicidal compounds for rice cultivation.

MATERIALS AND METHODS

A field experiment was carried out at the 'C' Unit Farm of Bidhan Chandra Krishi Viswavidyalaya in Kalyani, Nadia, West Bengal during the *kharif* seasons of 2017 and 2018. This farm is geographically located at 22°58′ N latitude and 88°3′E longitude along with an altitude of 9.75m above mean sea level at New Alluvial Zone of West Bengal having sub-humid sub-tropical climatic condition. The topographical feature of the land can be mentioned as medium-land situation. Initial soil samples of research field were assembled indiscriminately from dissimilar sites in 0-15 cm bottom of soil by using an auger, then completely stirred, desiccated, sieved and kept in polythene bags as per required volume for soil analysis. The textural class of the soil was sandy clay loam type having a pH of 7.2 with 0.57% organic carbon content, 183.26 kg ha^{-1} total nitrogen content, available phosphorus and potassium were 16.80 and 132 kg ha^{-1} respectively. This experiment was plotted in Completely Randomized Block Design (CRBD) comprising of 8 treatments replicated 3 times viz., T_1: Oxyfluorfen 23.5%EC @ 650 ml ha^{-1}, T_2: Oxyfluorfen 23.5%EC @ 1000 ml ha^{-1}, T_3: Butachlor 50%EC @ 1.25 kg ha^{-1}, T_4: Anilophos 30%EC @ 0.4 kg ha^{-1}, T_5: Pyrazosulfuron ethyl 10%WP @ 150 g ha^{-1}, T_6: Untreated control (weedy check), T_7: Untreated control (weed free check), and T_8: Oxyfluorfen 23.5%EC @ 2000 ml ha^{-1} to investigate phytotoxicity effects. Seeds of IET 4786 (Satabdi) were sown directly at 2 cm depth in 20 m^2 plot. Spacing maintained 20 cm × 10 cm. The state govt. recommended dose of fertilizers (RDF) for kharif rice as 60: 30: 30 kg ha^{-1} (N: P_2O_5: K_2O) was applied to all the plots. N, P and K were supplied to the crops using urea, SSP, and MOP as the respective sources for each nutrient. During the final land preparation, a quarter of the required quantity of inorganic nitrogen was applied as basal, along with the complete doses of phosphorus and potassium. Subsequently, rest ¾th of the N was top-dressed, with 1/2 of it applied at the time of active tillering and the remaining quarter during panicle initiation. Three different dosages of the test herbicide Oxyfluorfen 23.5%EC were sprayed @ 650, 1000 and 2000 ml ha^{-1} along with standard herbicides viz., Butachlor 50%EC @ 1.25 kg ha^{-1}, Anilophos 30%EC @ 0.4 kg ha^{-1} and Pyrazosulfuron ethyl 10%WP @ 150 g ha^{-1} , sprayed at one day after sowing (DAS) as pre-emergence herbicide using a flat fan nozzle equipped knapsack sprayer with a spray fluid of 500 L ha^{-1}. Untreated control treatments both weed free check (T_7) and weedy check (T_6) were also maintained to compare. Two sprayings of fipronil 5% SC @ 1 ml per lit of water were done at 65 and 80 DAS to protect the crop against insect-pests. Application of any fungicide was not required due to disease infestation was below the threshold limit. Yellow sarson was sown as follow up crop after direct seeded kharif rice to investigate the residual effects of various weed control methods implemented during the rice cultivation.

Bio-efficacy of herbicides

The population of dominant weeds, including broadleaves, grasses, and sedges, was recorded based on individual species in a designated square meter area at four different time points: 15, 30, 45, and 60 days after the application (DAA) of herbicides. Dry weight of weeds was taken as per species wise at 30, 45 and 60 days after herbicides application. To assess both weed dry weight and density of the weed flora, a 50 cm x 50 cm quadrat was placed twice within each plot to evaluate the relative efficacy of the herbicides. Observed value were then reported on a per square meter (m^{-2}) basis. Based on the dry weight of weed, the weed control efficiency was determined. This efficiency measure helps to determine the effectiveness of the weed control methods in reducing the overall weed biomass in the treated area.

Yield parameters of rice

To evaluate the yield attributing characters, 10 panicles were randomly collected from each plot. These selected panicles were used to measure various attributes, including weight and length of the panicles, test weight, and the number of filled grains per panicle. This sampling method allows for an accurate assessment of the rice crop's yield-related features in the study. The harvesting process was carried out on a plot-wise basis, ensuring careful manual handling to prevent any mixture with crops from other plots. Subsequently, after harvesting rice crop was allowed to remain in the field for a period of 2 to 3 days to facilitate sun-drying of the straw. This sun-drying step helps in reducing moisture content and preparing the crop for further processing or storage. After tagging the produce from each plot, it was brought to the threshing area and physically threshed there individually for each plot. This ensures that the straw and grains from each individual plot are kept distinct. After the necessary cleaning, drying, and winnowing processes, the grains, with an approximate moisture content of 14%, and the straw from individual plot were separately weighed. The yields for both the grains and the straw were then recorded. Then this obtained yield converted into t ha^{-1}.

Mechanical and physico-chemical properties of soil

During crop harvest, samples of soil from each plot of experimentation were collected from the spaces across the rows. Samples were collected from 0-15 cm depth soil profile. Required samples of each treatment were taken separately for analysis along with each replication for each weed control treatment. Below is a list of the several techniques followed to analyse the physical, chemical, and mechanical characteristics of the soil of experimentation.

Table 1: Methods employed for analyzing mechanical and physico- chemical properties of soil (0-15 cm depth)

Properties	Methods
A. Mechanical composition Sand, silt and clay (%)	Pipette Method (Piper, 1966)
B. Physical composition Bulk density (g cc^{-1}) Moisture content (%) Water holding capacity (%)	Field method (Bodman, 1942) Field method Keens Box method (Piper, 1966)
C. Chemical composition Soil pH Electrical Conductivity (EC) Organic Carbon (%) Total Nitrogen (%) Available Phosphorus (kg ha^{-1}) Available Potash (kg ha^{-1})	pH meter (Jackson, 1973) Conductivity Meter (Jackson, 1973) Volumetric Redox Titration Method (Walkley and Black, 1934) Modified Macro kjeldahl Distillation Method (Jackson, 1973) Olsen's Method (Jackson, 1973) Flame Photometer Method (Jackson, 1973)

Soil microbial population count

At crop harvest, samples of soil from each plot of experimentation were collected from the spaces across the rows. Samples were collected from 0-15 cm depth soil profile at pre-treatment, 15, 30, 45 and 60 DAA of herbicides. Soil samples were collected from different locations within each replicate of the same treatment, the samples were combined to create a composite sample. From this composite sample, specific samples for microbial analysis were taken. The analysis was conducted using dilution plating standard methods, which involve diluting the soil sample and then using it to plate microbial colonies for counting and further analysis. For the specific micro-organism *i.e.,* bacteria (Thornton's agar medium, 1922), fungi (Martin's Rose Bengal Streptomycin in agar media, 1950) and actinomycetes (Jensen's agar medium, 1942) particular growing media was made.

The plated samples were then placed in a BOD incubator and incubated at a controlled temperature of 28±1°C for various durations, typically up to 7 days. During this incubation period, observations were made to count the number of microbial colonies present on each plate at 3, 5 and 7 days.

RESULTS AND DISCUSSION

Weed flora

Broadleaf weeds like *Ludwigia parviflora*, *Eclipta alba*, *Alternanthera* sp., *Marsilea quadrifoliate*, grasses like *Echinochloa colona*, *E. crusgalli*, and sedges like *Cyperus rotundus*, *C. iria*, among others, were abundant in the trial field. The presence of same weed species in transplanted rice fields has been documented in studies conducted by other researchers (Mahajan *et al.*, 2009; Mohanty *et al.*, 2015 and Pattanayak *et al.*, 2022). All the treatments have been observed to control weeds with different efficiency except untreated control (weedy check) plot. Weed density was recorded at 15, 30, 45 and 60 DAT of rice and has been presented in Fig. 1. At every stage of the observation, the weedy check plot had the greatest weed density, which was succeeded by the treatment of Oxyfluorfen

23.5% EC @ 650 ml ha^{-1} (T_1). The untreated control (weed free check) plot had the lowest weed density, followed by T_2 (Oxyfluorfen 23.5% EC @ 1000 ml ha^{-1}). Table no. 2 lists the observations made about the weed dry weight at 30, 45, and 60 DAA (days after the application) of herbicides. Weeds' ability to grow is indicated by their dry weight and competitive ability of weeds with the crop is recognized in a better way by this indicator. The greatest weed biomass and growth were observed in untreated control plots. Application of Oxyfluorfen 23.5%EC @ 2000 ml ha^{-1} observed slightly better weed control efficiency in rice than applied @ 1000 ml ha^{-1} but depletion in grain yield was found at greater concentration of Oxyfluorfen due to adverse impact on plant growth which reflected in yield contributing characters and yield. Type of weeds specific estimates of weed control efficiency were made using data on the weed dry weight collected at 30, 45, and 60 days following herbicide treatment and that has been presented in Fig. 2. Untreated control (weed free check) plot recorded with maximum weed control efficiency (WCE). Same result was also obtained by Kashyap *et al*. (2019). Oxyfluorfen 23.5%EC @ 2000 ml ha^{-1}, one of the chemical herbicide treatments, had the greatest WCE followed by T_2 treatment. Though better weed control efficiency was achieved in higher dose of Oxyfluorfen 23.5% EC but it reduced grain yield of rice because of creating adverse impact on plant growth as well as yield contributing characters. Due to herbicides' superior potency, this progressively declines with time after application; greater weed control efficiency was seen during the early development phases of the rice crop.

Yield parameters of rice

The outcome of the experiment showed that the influence of various chemical weed management strategies on yield attributes and rice yields was significant. Rice yield attributes and yield were noted at crop harvest and are shown in Table no. 3. Observed data depicted that the superior yield attributing parameters *i.e.*, maximum number of effective tillers per m^2 and filled grains per panicle, panicle length and weight, weight of 1000 grains and rice yield were obtained from untreated control (weed free check) plot because of proper control measure for weeds throughout the crop growing phase, that ensure adequate nutrients, moisture, space and light for robust plant development. Resisting nutrients draining through controlling weeds results in higher yield of rice (Pratap *et al*., 2023). However, poor rice yield and yield attributes were observed in T_6 treatment (untreated control) plot due to dense infestation of weeds. Inferior yield attributing traits of rice in untreated control plot was noticed as a result of nutrients depletion by weeds and adverse surroundings generated by weeds. Our observations are in line with the findings reported by Reddy *et al*. (2012), Kumar *et al*. (2014), Sanodiya and Singh (2017), and Chaudhary *et al*. (2018). 67% decrease in rice yield in untreated control plot was observed by Karthika *et al*. (2019). Application of chemical herbicides significantly upgraded the rice yield and yield attributes over the untreated control plot. Oxyfluorfen 23.5% EC @ 1000 ml ha^{-1} (T_2) reported the highest number of effective tillers per m^2 and filled grains panicle^{-1}, panicle length and weight, weight of 1000 grains and rice yield when compared to other chemical weed control methods because it was more effective at controlling weeds by reducing weed dry weight and density, which prevented it from having any unfavorable effects on the plants.

Physico-chemical properties of soil

After harvest of rice, the impact of various weed control techniques on soil mechanical, physical, and chemical characteristics were observed. The results are shown in table no. 4. At crop harvest, due to various weed management strategies, soil physical qualities such as soil bulk density (BD), water holding capacity (WHC), moisture content (%), and soil mechanical properties such as distinct soil textural classification, percentage (%) of sand, silt, and clay remained unchanged. When it comes to the chemical characteristics of soil, various treatments have minimal impact on soil organic carbon (SOC), soil electrical conductivity (EC), and soil pH whereas total nitrogen (%), and available P_2O_5 and K_2O (kg ha^{-1}) in post-harvest soil varied significantly because of higher uptake by the rice crop itself. Highest total N content, available P_2O_5 and available K_2O (181.10, 16.15 and 129.80 kg ha^{-1}, respectively) was recorded from untreated control (weedy check) plot as a consequence of weed and crop roots existence in the soil that are used by soil microflora to accelerate the mineralization procedure also due to minimum dry matter accession by the crop. These findings are also in accordance with Kumari *et al*. (2023) and Mir *et al*. (2023). In the untreated control (weed free check) plot, the lowest nutrients content (175.49, 15.06, and 126.8 kg ha^{-1}, respectively) were observed because of more uptake of nutrients by rice to yield higher dry matter in weed free situation. Similar result was found by Sarma *et al*. (2024). Absorption of nutrients is faster and higher in weeds (Balasubramanian and Palaniappan, 2004) than crops so better weed management from the start limited the weeds' ability to extract nutrients, which led to the maximum soil nutrients in untreated control (weedy check) plot. Anilophos 30%EC @ 0.4 kg ha^{-1} application, reported the highest total nitrogen content and available P_2O_5, and K_2O, compare to other chemical weed control methods.

Total microbial population

The total microbial population was greatly impacted by weed management strategies used on rice. The impact of the different weed control measures on various soil micro-organism *viz.* total actinomycetes, total bacteria (*Bacillus* spp., *Pseudomonas fluorescence*), and total fungi (*Trichoderma viridae*, *T. harzianum*) were observed time to time i.e., pre-treatment, 15, 30, 45 and 60 DAA of treatments (Table 5). Total population of microbes *i.e.*, bacteria, actinomycetes and fungi in the rhizosphere rice soil had no appreciable impact by different treatments at the beginning of the rice crop growth stage, but significant differences between the treated and untreated plots were observed up to 45 DAA of the chemical herbicides. Adhikary *et al*. (2014) also reported a similar outcome. Though different herbicide applications have shown significant adverse effect on total microbial population until 45 DAA and 60 DAA, the population in herbicide-treated plots had significantly grown to the same level as that of the untreated control plots. Untreated control (weed fee check) plot recorded maximum no of bacteria at 30 and 45 DAA and highest no of fungi and actinomycetes up to 45 DAA. Reduction of microbial population was found at every herbicide treated plots from 15 DAA, higher herbicide concentrations, however, led to a greater reduction in microbial count. This finding was in accordance with Latha and Gopal (2010), and Ramalakshmi *et al*. (2017). Earlier to degeneration, impact of herbicides is detrimental on soil microorganisms which creates a reason to minimize their sufficiency as well as activity and after degradation the degraded products need some time to agglomerate in the soil, also to make an impact on microflora (Dhaker *et al*., 2020). At later stages of crop growth soil microflora population commences to increase when the weeds got demolished as an effect of herbicides and got mixed with soil which acts as nutrients augmentation in soil (Omara and Ghandor, 2018). The different treatments failed to substantially differ among themselves in any of the three situations (total bacteria, fungi, and actinomycetes) at first observation, however, following the application of multiple herbicides, they do so very quickly. Certain microbes had the potential to breakdown the herbicide, while others were negatively impacted by their application type and dosage (Sebiomo *et al*., 2011). This was also been supported by Zain *et al*. (2013), who stated that, relying on the different species of microorganisms, application amount and type of chemical and environmental aspects, herbicides may boost or restrict the progress in development of microorganisms. Microorganisms use herbicides as a supply of biogenic components for their physiological activities since they can break down herbicides. Herbicides diminish microorganism activity, abundance, and variety before causing them to degrade since they have harmful effects on those species. The toxic effect of herbicides is often at its peak just after treatment since their level in soil is at its greatest, but as time goes on, microbes breakdown the herbicides, and their level steadily decreases. The total number of soil microorganisms then rises as a result of carbon released by the degrading herbicide. These results corroborated with the findings of Bera and Ghosh (2013).

Residual effects of herbicides on succeeding crop

Table No. 6 shows the outcomes of the experiment on the effects of chemical-based weed management techniques on subsequent crops. Variation in germination percentage, growth and yield of yellow sarson was non-significant due to variation different chemical herbicides applied on previous rice crop. No negative impact was found on yellow sarson, grown as succeeding crop after *kharif* rice.

Phytotoxicity study

The phytotoxicity rating scale (PRS) was used as a basis for observation on phytotoxicity of the herbicides applied to the rice plants and its lingering impact on yellow sarson as the subsequent crop. The indicators of phytotoxicity used in this study were vein clearance levels, epinasty, hyponasty, and damage to the tips or surface of leaves. At 10, 20, 30, 45, and 60 days after the treatment application, the degree of phytotoxicity was observed by visual evaluation of the crop response and rated in the scale of 0-10. No phytotoxicity was found in any above-mentioned parameters for any treatments.

Table 2: Weed dry weight (g m^{-2}) in direct seeded *kharif* rice at 30, 45 and 60 days after application (DAA) of herbicide [Pooled]

Treatment	30 DAA								45 DAA							60 DAA								
	Grasses		Sedges		Broad leaf weeds				Grasses		Sedges		Broad leaf weeds			Grasses			Sedges		Broad leaf weeds			
	E. crusgalli	***E. colona***	***C. iria***	***C. rotundus***	***L. purviflora***	***E. alba***	***Alternanthera* sp.**	***M. quadrifoliata***	***E. crusgalli***	***E. colona***	***C. iria***	***C. rotundus***	***L. purviflora***	***E. alba***	***Alternanthera* sp.**	***E. crusgalli***	***E. crusgalli***	***E. colona***	***C. iria***	***C. rotundus***	***L. purviflora***	***E. alba***	***Alternanthera* sp.**	***M. quadrifoliata***
T_1	6.90	6.30	2.87	3.70	1.03	0.80	0.87	0.53	10.50	10.70	5.30	5.50	2.30	2.20	2.47	1.53	21.50	16.80	10.47	9.97	4.73	4.70	4.87	3.23
	(2.81)	(2.70)	(1.96)	(2.17)	(1.42)	(1.34)	(1.36)	(1.24)	(3.39)	(3.42)	(2.51)	(2.55)	(1.81)	(1.79)	(1.86)	(1.59)	(4.74)	(4.22)	(3.38)	(3.31)	(2.39)	(2.39)	(2.42)	(2.06)
T_2	2.97	3.57	1.87	2.47	0.43	0.23	0.27	0.20	4.03	4.57	3.23	3.50	1.23	1.30	1.43	0.87	12.70	7.00	5.83	7.37	3.13	2.93	3.03	2.70
	(1.99)	(2.13)	(1.69)	(1.85)	(1.19)	(1.11)	(1.13)	(1.09)	(2.24)	(2.35)	(2.06)	(2.12)	(1.49)	(1.51)	(1.56)	(1.36)	(3.70)	(2.82)	(2.61)	(2.89)	(2.03)	(1.98)	(2.01)	(1.92)
T_3	5.43	4.90	2.63	2.63	0.60	0.33	0.43	0.33	5.47	7.17	4.73	4.27	1.80	1.73	1.90	1.33	15.97	11.40	6.73	9.23	3.47	3.50	3.57	2.87
	(2.54)	(2.42)	(1.90)	(1.89)	(1.26)	(1.15)	(1.20)	(1.15)	(2.54)	(2.86)	(2.39)	(2.29)	(1.67)	(1.65)	(1.70)	(1.53)	(4.12)	(3.52)	(2.77)	(3.20)	(2.11)	(2.12)	(2.14)	(1.96)
T_4	6.33	5.90	3.23	3.80	0.97	0.93	0.63	0.47	12.00	10.90	5.83	5.60	2.37	2.47	2.17	1.77	17.93	17.97	10.57	11.13	4.90	3.90	4.53	3.33
	(2.71)	(2.62)	(2.05)	(2.19)	(1.40)	(1.39)	(1.28)	(1.21)	(3.60)	(3.45)	(2.61)	(2.56)	(1.83)	(1.86)	(1.78)	(1.66)	(4.33)	(4.35)	(3.40)	(3.47)	(2.43)	(2.21)	(2.35)	(2.08)
T_5	4.67	4.57	2.40	2.50	0.37	0.27	0.30	0.23	5.23	6.50	3.50	3.40	1.60	1.50	1.77	1.20	14.67	6.43	6.37	7.93	3.00	3.23	2.67	2.73
	(2.38)	(2.36)	(1.84)	(1.87)	(1.17)	(1.13)	(1.14)	(1.11)	(2.49)	(2.74)	(2.12)	(2.10)	(1.61)	(1.58)	(1.66)	(1.48)	(3.94)	(2.72)	(2.71)	(2.98)	(2.00)	(2.06)	(1.91)	(1.93)
T_6	38.40	37.53	14.20	17.97	5.23	5.53	4.53	3.47	58.73	65.23	20.90	29.90	8.77	8.60	6.80	7.53	81.80	72.67	31.63	33.83	10.93	13.10	13.63	9.57
	(6.27)	(6.20)	(3.90)	(4.35)	(2.49)	(2.55)	(2.35)	(2.11)	(7.73)	(8.13)	(4.68)	(5.55)	(3.12)	(3.10)	(2.79)	(2.92)	(9.10)	(8.58)	(5.71)	(5.89)	(3.45)	(3.75)	(3.82)	(3.25)
T_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)	(1.00)
T_8	2.83	2.63	1.67	2.27	0.23	0.17	0.20	0.13	3.37	2.63	2.87	3.03	1.10	1.20	1.23	0.67	8.30	6.27	4.40	5.13	2.37	2.63	2.10	2.33
	(1.96)	(1.90)	(1.63)	(1.81)	(1.11)	(1.08)	(1.09)	(1.06)	(2.08)	(1.90)	(1.96)	(2.01)	(1.44)	(1.48)	(1.49)	(1.29)	(3.05)	(2.69)	(2.32)	(2.48)	(1.83)	(1.90)	(1.76)	(1.82)
S.Em (±)	**0.08**	**0.10**	**0.09**	**0.09**	**0.06**	**0.05**	**0.05**	**0.03**	**0.13**	**0.11**	**0.08**	**0.11**	**0.07**	**0.07**	**0.05**	**0.07**	**0.15**	**0.12**	**0.10**	**0.14**	**0.06**	**0.08**	**0.06**	**0.07**
C.D. (0.05)	**0.25**	**0.30**	**0.27**	**0.26**	**0.20**	**0.14**	**0.14**	**0.10**	**0.38**	**0.34**	**0.23**	**0.33**	**0.22**	**0.21**	**0.15**	**0.22**	**0.44**	**0.35**	**0.30**	**0.44**	**0.20**	**0.26**	**0.17**	**0.20**

Table 3: Effective tillers, Panicle characterization and yield of direct seeded *kharif* rice as influenced by different weed control measures [Pooled]

Treatment	Effective tillers m^{-2}	Panicle length(cm)	Panicle weight (g)	No. of filled grains panicle^{-1}	1000 grain wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
T_1	290.1	22.2	1.99	66.8	18.2	3.15	4.30	7.45	42.28
T_2	317.4	25.1	2.49	80.1	18.8	4.38	4.92	9.30	47.10
T_3	298.8	23.4	2.14	70.9	18.6	3.64	4.36	8.00	45.50
T_4	289.8	21.6	1.96	62.5	18.0	3.00	3.93	6.93	43.29
T_5	300.5	23.5	2.18	72.8	18.7	3.74	4.59	8.33	44.90
T_6	278.5	21.1	1.74	58.1	17.9	2.42	3.50	5.92	40.88
T_7	319.0	25.3	2.51	81.6	18.9	4.50	4.98	9.48	47.47
T_8	307.4	24.0	2.25	75.7	18.8	3.94	4.75	8.69	45.34
S.Em (±)	**4.02**	**0.30**	**0.02**	**2.63**	**0.42**	**0.14**	**0.09**	**0.32**	**--**
C.D. (0.05)	**12.1**	**0.90**	**0.07**	**7.90**	**NS**	**0.41**	**0.26**	**0.97**	**--**

Table 4: Physical, mechanical and chemical properties of the experimental soil at rice crop harvest [Pooled]

Treatments	BD (gm cc^{-1})	Moisture Content (%)	WHC (%)	Sand (%)	Silt (%)	Clay (%)	pH	EC (dS m^{-1})	Organic Carbon (%)	Total N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1	1.52	17.9	58.6	48.72	26.19	25.09	7.21	2.21	0.55	179.83	15.97	129.0
T_2	1.52	18.2	57.7	48.92	26.15	24.93	7.22	2.24	0.54	176.85	15.70	127.4
T_3	1.53	18.4	58.7	47.95	26.67	25.38	7.23	2.22	0.58	178.91	15.94	128.7
T_4	1.56	19.0	58.5	48.35	26.83	24.82	7.23	2.21	0.56	180.63	16.00	129.5
T_5	1.54	18.6	59.4	48.35	27.04	24.61	7.24	2.26	0.54	178.96	15.90	128.5
T_6	1.52	18.1	58.6	47.37	26.86	25.77	7.25	2.21	0.56	181.10	16.15	129.8
T_7	1.53	18.7	57.7	48.15	26.61	25.24	7.25	2.27	0.59	175.49	15.06	126.8
T_8	1.54	17.7	58.6	48.78	26.92	24.30	7.21	2.20	0.54	177.54	15.85	128.3
S.Em (±)	**0.03**	**0.13**	**0.20**	**0.10**	**0.12**	**0.15**	**0.05**	**0.04**	**0.01**	**1.55**	**0.10**	**0.74**
C.D. (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**4.70**	**0.30**	**2.23**

Table 5: Influence of treatments on population of total bacteria, fungi and actinomycetes (CFU x 10^6 g^{-1} of soil) [Pooled]

Treatments	Microbial population (CFU x 10^6 g^{-1} of soil)														
	Bacteria					Fungi					Actinomycetes				
	Initial	15 DAA	30 DAA	45 DAA	60 DAA	Initial	15 DAA	30 DAA	45 DAA	60 DAA	Initial	15 DAA	30 DAA	45 DAA	60 DAA
T_1	35.52	27.62	32.74	34.54	85.62	55.31	34.83	36.52	45.53	88.45	55.34	35.23	37.72	43.41	89.57
T_2	34.66	24.52	29.56	36.35	101.82	54.68	28.94	30.84	44.38	98.47	54.29	31.29	33.59	44.52	96.17
T_3	35.75	26.47	30.42	35.85	90.25	56.85	30.32	32.35	42.64	96.68	56.68	32.82	33.52	41.55	99.38
T_4	35.54	22.15	31.82	35.23	87.71	55.82	26.62	28.78	42.89	94.29	55.75	30.56	32.87	42.68	98.73
T_5	36.72	20.49	30.24	35.21	95.56	55.93	24.52	27.37	43.47	91.18	56.83	29.43	32.18	43.75	95.96
T_6	35.62	51.82	55.27	57.14	102.26	55.57	55.52	56.23	57.24	82.57	54.32	56.42	61.29	64.58	93.57
T_7	36.32	48.25	56.18	59.64	103.52	54.34	57.62	58.72	59.56	98.65	56.24	57.94	62.57	65.92	97.95
T_8	36.74	11.28	22.58	34.25	81.41	54.28	14.57	20.45	37.89	84.58	53.47	21.45	25.87	36.87	84.34
S.Em (±)	0.25	0.70	1.07	1.40	0.53	0.35	1.04	1.07	1.73	0.48	0.30	0.39	0.75	1.07	0.45
C.D. (0.05)	NS	2.12	3.21	4.22	NS	NS	3.13	3.22	5.21	NS	NS	1.17	2.26	3.23	NS

Table 6: Germination (%), seed yield and ancillary characters of yellow sarson as follow up crop as influenced by different weed control measures applied in direct seeded *kharif* rice crop [Pooled]

Treatment (Applied in main crop rice)	**Germination % at 15 DAS**	**Plant population m^{-2} at 30 DAS**	**Plant height at harvest (cm)**	**Siliqua per plant at harvest**	**Seeds per siliqua harvest**	**Seed yield ($kg\ ha^{-1}$)**
T_1	98.5	33.00	74.4	72.9	18.80	1078
T_2	99.5	33.33	74.7	74.1	18.92	1100
T_3	99.2	32.67	74.6	73.6	18.87	1093
T_4	96.2	28.67	74.2	72.3	18.75	1062
T_5	98.6	33.33	74.6	73.0	18.80	1088
T_6	99.0	32.33	74.3	72.1	18.60	1038
T_7	99.1	33.33	74.7	72.8	18.81	1075
T_8	98.3	30.33	74.2	72.3	18.70	1055
S.Em (±)	1.17	0.59	1.22	0.70	0.32	1.25
C.D. (0.05)	NS	NS	NS	NS	NS	NS

CONCLUSION

Oxyfluorfen 23.5% EC with a dose rate of 1000 ml ha^{-1} may be an effective and suitable chemical based weed management strategy for direct seeded *kharif* rice which does not have any residual as well as phytotoxic effect in succeeding crop(s).

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