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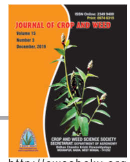

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Efficacy of herbicides against weeds in rice (*Oryza sativa* L.) - lathyrus cropping system

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ABSTRACT

A field trial was conducted at Regional Research Sub-Station (new alluvial zone) of Bidhan Chandra Krishi Viswavidyalaya, Chakdaha, Nadia, West Bengal during kharif and rabi seasons of *2016-17 and 2017-18 to study the efficacy of different herbicides against diverse weed population and their effect on succeeding lathyrus crop. Among different chemical herbicides, Almix 20 WP @ 4 g ha^{-1} applied as early post emergence (EPOE) (at 15 days after transplanting) effectively controlled all categories of weeds (grass, sedge, broad leaf) resulted minimum weed density, minimum weed biomass, higher weed control efficiency (WCE) at 30 and 45 days after transplanting (DAT) which ultimately produced higher grain yield of kharif rice (3.24 t ha^{-1}) compare to other treatments. Yield increment in succeeding lathyrus crop (rabi season) was also noticed with this herbicide. Superiority of Almix 20 WP @ 4 g/ha was also reflected with respect to phytotoxicity and soil microbial population and economics.*

Keywords: Herbicides, paddy, lathyrus, microbial population, yield

Rice (*Oryza sativa* L.) occupies a pivotal place in Indian agriculture and it is the staple food for more than 70% of population and a source of livelihood for about 120-150 million rural households. It contributes about 43% of total food grain production and 46% of total cereal production in the country (Directorate of Rice Development, 2011). India needs to produce 120 mt of rice by 2030 to feed its one and a half billion plus population (Adhya, 2011). There is no scope for horizontal expansion of cultivable area. Therefore, rice productivity and production has to be increased to meet the future demand.

Weed is considered as a major pest and constraint to increase the production of rice. In India, weed control takes 30-35% share of total cost of crop production and the average yield loss is caused to the tune of 41.2%. Under new alluvial zone of West Bengal, the biological yield loss of rice due to weed was 37.02% and 23.12% in grain and straw, respectively (Mondal *et al.*, 2015). This illustrates the importance of weed control in minimizing the yield losses and boosting up the crop productivity. Management of weeds at farm levels is still largely restricted to mechanical and cultural methods (Yaduraju and Mishra, 2002). Proper management of weeds, in time, to reduce the crop-weed competition is not possible due to sharp increase in the wage and unavailability of labour due to industrialization and urbanization. In view of this, chemical weed control is becoming more popular throughout the world. Major competition with weeds in rice field occurs during initial 15-30 days after seeding or germination in direct seeded rice and 30-60 days in transplanted rice. Therefore, it calls for a detailed study on weed flora in different paddy cultures (transplanted as well as direct seeded paddy) keeping an eye to develop an efficient eco-safe weed management practice for rice cultivation to replace those indigenous method of weed control through the use of effective, economic, socially and environmentally safe chemicals at proper dose, proper time and method of application.

MATERIALS AND METHODS

Field trial was set up at Regional Research Sub-Station (RRS) of Bidhan Chandra Krishi Viswavidyalaya, Chakdaha, West Bengal, India (23°5.3´ N latitude, 83°5.3´ E longitude and 9.75 m above mean sealevel) during *kharif* and *rabi* seasons of 2016-17 and 2017-18in transplanted rice (*cv.* 'IET 4786' or 'Satabdi') under medium land situation. The soil was having sandy clay loam type texture, pH of 6.5, organic carbon 0.68%, available nitrogen (N) 215.2 kg ha^{-1}, available phosphorus (P) 25.2 kg ha^{-1} and available potassium (K) 142.4 kg ha^{-1}.Weekly maximum and minimum temperatures ranged between 32.3 to 36.8°C and 15.2 and 28.2°C during 2016 and 2017, respectively. Maximum relative humidity ranged from 90 to 92.3% in 2016 and 90.2 to 93.1% in 2017, respectively. The annual rainfall during the experimental period was 1260.0 and 1430.5 mm in 2016 and 2017, respectively.The experiment was laid out in randomized block design with ten treatments consisting of 2, 4-D ethyl ester (38 EC) at five different dosages (425, 850, 1280, 1700 and 3400 g ha^{-1}), Butachlor (50 EC) @ 1000 g ha^{-1}, Bispyribac sodium (10 SC) @ 25 g ha^{-1} and Almix

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(20 WP) @ 4 g ha^{-1}, hand weeding at 20 and 40 DAT and control or weedy plot with three replications. The individual plot size was 5 × 4m. The amount of the herbicides was calculated as per treatments on the basis of gross plot area and was broadcasted uniformly in the experimental plots as per treatments. The herbicide 2, 4-D ethyl ester (38 EC) was applied 25 DAT and others were applied 15 DAT with their different doses.

Healthy paddy seeds (*cv.* IET 4786) were soaked for 24 hours in clean water for better germination. The seeds were treated with *Trichoderma viride* @ 4 g kg^{-1} and shade-drying for 6 hours prior to sowing. Well germinated seeds were sown on 27th and 29th June in 2016 and 2017, respectively. Twenty two days old seedlings were transplanted @ 3 seedlings $hill^{-1}$ at a spacing of 20 × 15cm in both the years. All other cultural and plant-protection measures were also adopted as recommended for the region (Banerjee and Pal, 2009). The individual plot size was 5 × 4m. One-fourth (¼th) N along with full P_2O_5 and ¾th K_2O of RDF were applied as basal (during final land preparation). Remaining ½ N was top-dressed at tillering stage, while ¼th each of N and K_2O was given at panicle initiation stage. Organic manures were applied 7 days before transplanting just to substitute a part of recommended dose of N. However, eco-safe protection measures were taken against yellow stem borer and rice bug. The crops were harvested manually with sickle at a height of 25-30 cm from ground level on 5th and 9th October in 2016 and 2017, respectively. Then grain yield after threshing and cleaning was recorded from unit plot area and converted into t ha^{-1} at 15% moisture content. After harvesting of rice, lathyrus (cv. '*Nirmal'*) was sown on October 17, 2016 and October 22, 2017 and harvested on February 11, 2017 and February 16, 2018. Standard agronomic management suitable for that region was provided to the succeeding crop. An area of 0.25 m^2 was selected randomly at two spots by throwing a quadrate of 0.5 x 0.5 m. Weed species were counted from that area and density was expressed in number m^{-2}. The collected weeds were first sun-dried and then kept in an electric oven at 70°C till the weight became constant and dry weight was expressed as g m^{-2}. The data on crop growth parameters and yield were also recorded both for rice and succeeding lathyrus crops. To assess the bio-efficacy of different herbicides on crops and weeds, weed control efficiency (WCE) was worked out using following equations respectively as suggested by Banerjee *et al.* (2018):

$$\text{WCE} = \frac{\text{WDM}_c - \text{WDM}_t}{\text{WDM}_c} \times 100$$

Where, WDM_c is the weed dry matter weight (g m^{-2}) in control plot; WDM_t is the weed dry matter weight (g m^{-2}) in treated plot. The total monetary returns (gross return) of the economic produce obtain from rice crop were calculated based on minimum support prices (15.25 kg^{-1}) of Government of India for rice. The gross return is expressed per hectare basis using following equation: Gross return = rice yield × minimum support prices.

Net return per hectare basis was calculated by subtracting the total cost of cultivation from the gross returns. Benefit : cost ratio (B : C ratio) was calculated as follows:

$$\text{B : C ratio} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

The enumeration of the microbial population was carried out on agar plates containing appropriate media following serial dilution technique and pour plate method (Pramer and Schmidt, 1965). All the collected data was subjected to analysis of variance (ANOVA) according to the techniques define for simple randomized complete block design (RCBD) as described by Gomez and Gomez (1984). The significant difference of sources of variation was tested at the probability level of 0.05. The standard error of the mean (SEm±) and the LSD (0.05) value were indicated in the tables to compare the difference between the mean values.

RESULT AND DISCUSSION

Weed population, weed biomass and weed control efficiency in rice field

The experimental plots were infested with mixed weed flora where broadleaved weeds (BLW) were the most dominating followed by grassy weeds and sedges, irrespective of the dates of observations. The least weed population and weed biomass in terms of grasses, sedges and broadleaf weeds were registered under weed-free check whereas maximum weed population was recorded under weedy check (Table 1). Among the tested herbicides the treatment plot received Almix 20 WP resulted lowest weed population (14.0 and 17.0 m^{-2} respectively for 30 and 45 DAT), accounting 52.8% and 52.0% less weed dry weight at 30 and 45 DAT, respectively than unweeded control. Consequently, weed biomass in plots receiving 2, 4-D ethyl ester (38 EC) @ 3400 g ha^{-1} was recorded 36.6% and 39.5% lower at 30 and 45 DAT than unweeded control, respectively. This treatment was found more effective against broadleaf weeds and failed to control grasses. Among the five different doses of 2,4-D ethyl ester, the highest dose exhibited the maximum bio-efficacy against weeds in the present study. The weed control efficiency also exhibited similar variations and thereby showing

Table 1: Weed population, biomass and weed control efficiency in transplanted *kharif* paddy (pooled data of 2 years)

Treatments	Grassy weeds		Sedge weeds		Broad leaf weeds		Total weed population (No. m^{-2})	Total weed dry weight (g m^{-2})	Weed control efficiency (%)
	Echinochloa Spp.	*Leptochloa chinensis*	*Cyperus iria*	*Cyperus difformis*	*Sphenoclea zeylannica*	*Sphenoclea octovalvis*			
30 DAT									
T1	2.10 (4.62)	2.34 (5.69)	2.30 (5.41)	2.26 (5.35)	1.23 (1.70)	1.23 (1.69)	41.1	8.70	23.23
T2	2.07 (4.55)	2.34 (5.65)	2.27 (5.40)	2.29 (5.30)	1.09 (1.25)	1.20 (1.54)	36.8	8.61	24.13
T3	2.06 (4.52)	2.32 (5.69)	2.27 (5.41)	2.28 (5.35)	1.03 (1.11)	1.03 (1.17)	34.9	7.98	29.64
T4	2.09 (4.54)	2.32 (5.69)	2.27 (5.43)	2.25 (5.32)	0.96 (0.98)	1.02 (1.10)	34.6	7.92	30.18
T5	2.08 (4.53)	2.33 (5.68)	2.25 (5.41)	2.23 (5.30)	0.82 (0.82)	0.90 (0.91)	32.3	7.20	36.60
T6	1.45 (2.24)	1.43 (2.17)	1.41 (2.10)	1.46 (2.30)	1.57 (2.64)	1.64 (2.87)	21.5	5.79	48.89
T7	1.34 (1.84)	1.36 (1.92)	1.31 (1.84)	1.48 (2.20)	1.49 (2.41)	1.59 (2.76)	19.5	5.61	50.62
T8	1.23 (1.55)	1.18 (1.53)	1.19 (1.50)	1.30 (1.74)	1.02 (1.19)	1.31 (1.84)	14.0	5.36	52.72
T9	1.02 (1.13)	1.05 (1.23)	0.90 (0.93)	1.08 (1.25)	1.03 (1.13)	1.30 (1.76)	11.2	4.92	56.66
T10	2.17 (4.72)	2.40 (5.77)	2.29 (5.62)	2.27 (5.41)	2.29 (5.51)	2.60 (6.88)	61.6	11.36	-
SEm±	**0.271**	**0.312**	**0.339**	**0.303**	**0.261**	**0.257**	-	-	-
LSD (0.05)	**0.805**	**0.927**	**1.007**	**0.900**	**0.775**	**0.764**	-	-	-
45 DAT									
T1	2.28 (5.47)	2.75 (7.99)	2.26 (5.31)	2.34 (5.57)	1.35 (1.93)	1.48 (2.36)	46.7	14.50	22.56
T2	2.28 (5.45)	2.74 (8.00)	2.26 (5.25)	2.27 (5.52)	1.18 (1.51)	1.34 (2.00)	42.4	14.26	24.01
T3	2.28 (5.45)	2.74 (8.02)	2.25 (5.21)	2.30 (5.53)	1.08 (1.25)	1.02 (1.19)	40.0	13.37	28.58
T4	2.29 (5.42)	2.76 (8.05)	2.21 (5.19)	2.27 (5.53)	0.97 (1.09)	0.98 (1.14)	39.1	12.67	32.31
T5	2.30 (5.46)	2.74 (8.03)	2.25 (5.23)	2.32 (5.55)	0.92 (1.00)	0.93 (0.95)	36.7	11.37	39.29
T6	1.55 (2.54)	1.70 (2.91)	1.49 (2.34)	1.46 (2.36)	1.63 (2.71)	1.68 (3.06)	23.9	9.67	48.41
T7	1.28 (2.03)	1.51 (2.33)	1.36 (2.05)	1.40 (2.08)	1.60 (2.65)	1.62 (2.91)	21.1	9.49	49.43
T8	1.24 (1.60)	1.36 (1.88)	1.25 (1.66)	1.25 (1.71)	1.33 (1.95)	1.52 (2.51)	17.0	9.01	51.82
T9	0.93 (1.00)	0.96 (1.04)	0.84 (0.75)	1.04 (1.09)	1.04 (1.20)	1.32 (1.83)	12.0	8.30	55.64
T10	2.32 (5.61)	2.80 (8.11)	2.25 (5.34)	2.34 (5.63)	2.39 (5.82)	2.65 (7.22)	65.0	18.78	-
SEm±	**0.330**	**0.392**	**0.304**	**0.293**	**0.252**	**0.314**	-	-	-
LSD (0.05)	**0.980**	**1.165**	**0.903**	**0.871**	**0.749**	**0.933**	-	-	-

Original figures in parentheses were subjected to square-root transformation ?(x=0.5) before statistical analysis; DAT, days after transplanting

Table 2: Growth attributes, yield components, yield and economics of transplanted *kharif* paddy (pooled data of 2 years)

Treatments	Plant height (cm) at 75 DAT	LAI at 45 DAT	No. of panicle m^{-2}	Panicle weight (g)	Panicle length (cm)	Percent filled grains $panicle^{-1}$	1000-grain weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest Index (%)	Gross return ($\times 10^{31}\ ha^{-1}$)	Net return ($\times 10^{3\ 1}\ ha^{-1}$)	B:C ratio
T_1	66.90	3.81	306	2.14	18.76	78.5	18.31	2.94	4.27	40.79	52.3	28.8	1.23
T_2	67.0	3.93	309	2.17	19.34	80.8	18.37	2.99	4.30	40.95	53.0	29.4	1.25
T_3	66.4	3.97	315	2.21	20.60	83.1	18.37	3.04	4.35	41.11	53.8	30.1	1.27
T_4	66.6	3.91	318	2.24	21.11	84.6	18.41	3.07	4.40	41.22	54.4	30.5	1.28
T_5	67.0	4.00	322	2.27	22.29	86.2	18.45	3.11	4.46	41.09	55.1	30.6	1.25
T_6	76.6	3.94	324	2.29	22.86	87.7	18.45	3.13	4.50	41.02	55.5	31.8	1.34
T_7	77.8	3.93	328	2.33	23.95	90.0	18.40	3.18	4.54	41.15	56.3	32.7	1.39
T_8	79.5	3.99	330	2.39	25.38	90.8	18.50	3.24	4.61	41.26	57.3	33.9	1.45
T_9	81.1	4.02	334	2.41	26.33	93.1	18.56	3.29	4.68	41.28	58.2	31.0	1.14
T_{10}	62.0	3.04	289	1.92	15.86	67.7	18.20	2.28	3.92	36.75	43.0	20.6	0.92
SEm±	1.25	0.03	2.04	0.06	0.48	2.29	0.06	0.04	0.04	0.39	-	-	-
LSD (0.05)	3.73	0.08	6.07	0.19	1.42	6.81	NS	0.11	0.12	1.15	-	-	-

DAT, Days after transplanting; LAI, Leaf area index;B:C ratio, benefit cost ratio;NS, Non-significant;

Table 3: Microbial population in the rhizosphere soil of transplanted *kharif* paddy (pooled data of 2 years)

Treatments	Total bacteria (CFU x 10^6)				Total actinomycetes (CFU x 10^5)				Total fungi (CFU x 10^4)			
	Initial	3 DAHA	15 DAHA	At harvest	Initial	3 DAHA	15 DAHA	At harvest	Initial	3 DAHA	15 DAHA	At harvest
T_1	133.9	86.4	92.2	148.0	136.6	80.2	90.1	128.3	16.1	7.9	8.5	13.4
T_2	135.3	84.0	94.3	148.5	139.5	78.9	90.0	127.9	16.1	7.3	8.0	13.7
T_3	134.6	84.0	99.6	152.3	137.8	82.3	91.4	125.9	16.0	7.4	7.9	13.4
T_4	135.7	81.3	96.7	150.9	138.2	78.3	87.0	128.0	15.7	7.7	8.3	13.1
T_5	134.7	80.8	92.1	147.0	136.6	78.1	86.1	122.0	15.8	7.0	7.7	12.9
T_6	135.5	96.4	83.4	144.6	139.0	88.1	76.1	128.2	15.8	8.1	6.8	13.1
T_7	133.5	93.6	81.6	144.4	139.3	89.8	72.8	124.6	16.4	7.8	7.0	13.5
T_8	134.6	99.1	86.4	147.8	138.5	86.2	73.9	128.2	16.1	7.9	7.3	13.8
T_9	135.7	137.9	149.1	151.5	137.5	125.6	128.2	132.6	15.8	15.3	15.1	14.7
T_{10}	135.0	138.4	133.2	127.3	139.7	133.0	117.0	109.0	15.7	14.8	12.0	11.2

DAHA, Days after herbicide application; CFU, colony forming unit.

Table 4: Weed population, growth attributes, yield components and economics of succeeding lathyrus crop (pooled data of 2 years)

Treatments	Weed population m^{-2}	Weed dry weight (g m^{-2})	Plant height (cm)	No. of branches plant^{-1}	Plant population m^{-2}	No of pods plant^{-1}	1000 seeds weight (g)	yield (t ha^{-1})	Gross return ($\times 10^{3}$ ^{1} ha^{-1})	Net return ($\times 10^{3}$ ^{1} ha^{-1})	B : C ratio
T_1	7.13	8.57	45.96	4.24	45.50	11.76	137.78	0.77	84.7	53.5	1.72
T_2	7.32	8.64	47.23	4.30	45.67	11.30	137.53	0.79	86.9	55.7	1.79
T_3	7.33	8.57	49.47	4.72	45.83	12.26	140.04	0.82	90.2	59.0	1.90
T_4	7.09	8.46	49.33	4.83	45.33	12.43	139.10	0.83	91.3	60.1	1.93
T_5	6.97	7.95	50.81	4.92	45.67	13.14	140.24	0.82	90.2	59.0	1.90
T_6	6.87	8.27	48.34	4.36	45.17	12.44	139.50	0.81	89.1	57.9	1.86
T_7	7.10	8.09	47.38	4.71	45.17	10.83	138.78	0.79	86.9	55.7	1.79
T_8	7.09	7.70	49.91	4.80	46.50	11.72	141.08	0.81	89.1	57.9	1.86
T_9	6.84	7.63	52.80	5.06	48.33	13.84	141.62	0.84	92.4	61.2	1.97
T_{10}	7.98	8.73	44.19	3.74	43.67	11.04	136.68	0.76	83.6	52.4	1.69
SEm±	**0.28**	**0.28**	**1.40**	**0.28**	**0.94**	**1.03**	**2.22**	**0.02**	-	-	-
LSD (0.05)	**0.83**	**0.82**	**4.17**	**NS**	**2.80**	**NS**	**NS**	**NS**	-	-	-

B:C ratio, benefit cost ratio; NS, Non-significant

superiority of Almix 20 WP with 55.9% and 56.5% higher WCE at 30 and 45 DAT over control treatment, respectively. Unlike other three herbicides used in this experiment, Almix, a sulfonyl urea group herbicide, was also found effective against all categories of weeds. As a mixture of metsulfuron methyl and chlorimuron ethyl, almix can control both grassy and broadleaf weeds. Better performance of this ready-mix herbicide can be attributed to inhibition of normal function of enzyme ALS/AHAS which is essential in amino acid (protein) synthesis. Without proteins, plants starve to death. These results were also in conformity with the findings of other investigators (Ghosh *et al.,* 2005; Ghosh and Ghosh, 2007; Pal *et al.,* 2012).

Growth attributes, yield components and yield of rice

Growth and yield components of *kharif* paddy were found to be the highest under two hand weedings at 20 and 40 DAT because of its capacity to control the broad spectrum of weed (grass + sedge + broadleaf) and thus reduce the competition for resources to the crop with the weeds. This was closely followed by Almix 20 WP @ 4 g ha^{-1} applied as early post emergence (EPOE), which produced crops with better growth and yield components. Crops receiving the above herbicide exhibited 28.3% more plant height at 60 DAT, 13.7% higher LAI at 60 DAT, 14.2% higher number of panicle m^{-2}, 24.5% panicle weight, 60.0% more panicle length, 34.1% higher percent filled grains panicle^{-1} and 12.2% higher harvest index over unweeded control (Table 2). Superior performance of Almix is attributed to its own capability to improve the crop growth by suppressing all categories of weeds, and thereby enabling the paddy crop to face minimum competition from weed and utilize more resources efficiently. Previous studies also reported minimum crop-weed competition in rice fields with almix (Banerjee *et al.,* 2005; Pal *et al.,* 2007). All the measured yield components were recorded lowest under control (weedy) treatment during both the years (Table 2). This might be due to greater crop-weed competition faced by the crop in weedy plots.

The *kharif* paddy produced highest grain and straw yields under weed free check. However, all the tested herbicides produced crops with significantly (*pd”0.05*) higher yield as compared to non-treated control. Differential herbicide management had resulted significant grain yield variation of rice *cv.* ‘Satabdi’ ranging from 2.28 to 3.29 t ha^{-1}. Among the herbicidal treatments, application of Almix 20 WP @ 4 g ha^{-1} as early post emergence (EPOE) (at 15 DAT) resulted maximum grain and straw yield, accounting 42.1% and 17.6% more than the yields obtained under unweeded control, respectively (Table 3). The higher yield with almix might be attributed to realization of higher growth and yield parameters as a result of greater inhibition of all weed flora by blocking the normal function of enzyme ALS/AHA (Pal *et al.,* 2007; Ghosh *et al.,* 2007). Advantages of herbicide application and judicious weed management strategies in improving yield components and yield of *kharif* paddy were earlier reported by Razzaq *et al*. (2010).

Economics of rice

In terms of monetary returns, all the weed control treatments were superior over control (weedy) treatment (Table 2). The highest net return and B:C ratio were fetched by Almix 20 WP @ 4 g ha^{-1}. However, the highest dose of 2,4-D ethyl ester (3400 g ha^{-1}) gave maximum return per rupee investment. Weedy plots resulted in lowest monetary returns due to poor crop yield realized at this growing situation. Some investigators reported similar results earlier (Kandasamy and Chinnuasamy, 2005).

Effect on soil microflora

Four different herbicides used in this experiment had different half-life and as a result based on degradation, the reduction on soil microflora population was also varied. But 2,4-Dethyl ester is potentially mobile and rapid degradation in soil takes place only within 1-2 weeks. All four tested herbicides brought about significant reduction in microbial population. There was an initial detrimental effect on microbial population upto the persistence period of all four herbicides and after degradation the microbial population was increased at a slow rate upto harvest. However, 2, 4-D ethyl ester at higher dose showed detrimental effects on soil microbes. The maximum reduction of soil microbial population was recorded at 3 days after herbicide application (DAHA) against the 2, 4-Dethyl ester (38 EC) application @ 3400 g ha^{-1} [bacteria (80.8 CFU x 10^6), actinomycetes (78.1 CFU x 10^5) and fungi (7.0 CFU x 10^4)]. The corresponding figures for Almix, Butachlor and Bispyribac sodium were 99.1, 96.4 and 93.6 CFU x 10^6 bacteria, 86.2, 88.1 & 89.8 CFU x 10^5 actinomycetes and 7.9, 8.1 & 7.8 CFU x 10^4 fungi, respectively (Table 3). At 15 DAHA, the reduction of soil microbial population was lower in plots treated with all these herbicides. At harvest, the soil microflora population was higher than that recorded in prior two observations under all four herbicidal treatments. Ghosh *et al.* (2007) also expressed similar views.

Weed population and weed dry weight in succeeding lathyrus field

Initial suppression of total weed flora, both in terms of decreased weed density and biomass at 30 days after sowing (DAS) was visualized in follow-up lathyrus crop due to different weed management practices applied to the preceding paddy plants. Initial suppression was might be due to the persistency activity. Adoption of hand weeding to the preceding transplanted paddy caused 12.6 and 13.4% lower weed population and dry weight respectively over the standard Almix. Application of 2, 4-Dethyl ester 38 EC @ 3400 g ha^{-1} control more broadleaf weed both in preceding paddy crop and succeeding lathyrus crop, accounting 14.5 and 9.8% lower weed population and dry weight in lathyrus, respectively at 30 DAS than weedy check. Furthermore, adoption of zero tillage management in succeeding lathyrus crop might have also helped to reduce the population of diverse weed flora.

Growth attributes, yield components and yield of succeeding lathyrus crop

All growth attributes and yield components of follow up zero-tilled lathyrus crop (Table 4) did not exhibit any significant variation among the different herbicidal treatment applied to previous crop. The crops receiving hand weeding treatment showed maximum growth and yield attributing characters probably due to lesser competition faced by lathyrus crop from the weeds. The application of 2, 4-D ethyl ester(38 EC) @ 3400 g ha^{-1} produced crops with 6.62 cm more height at harvest, 31.6% higher number of branch $plant^{-1}$, 4.6% more number of plant population m^{-2}, 19% more number of pods $plant^{-1}$ and 2.6% higher test weight over the weedy check plot. Lowest values of all growth and yield attributes from the untreated control plot were recorded.

Herbicidal treatments applied in paddy crop played a vital role in seed yield data of follow up lathyrus crop (Table 4). The treatments which gave best efficacy in paddy field also resulted the highest seed yield of succeeding lathyrus crop. The maximum seed yield of lathyrus was recorded with hand weeding treatment. Amongst the herbicidal treatments, application of 2,4-D ethyl ester @ 1700 g ha^{-1} resulted higher seed yield of lathyrus compared to weedy situation and other herbicide treatments. In contrary, severe weed interference could result in much lower seed yield in unweeded plots, emphasizing the need for weed control either in preceding rice or succeeding lathyrus crop.

Economics of succeeding lathyrus crop

Maximum net return per rupee investment was obtained with hand weeding twice (` 1.97), accounting 16.6% more than that of untreated control. Amongst the tested herbicides, application of 2, 4-D ethyl ester 38 EC @ 1700 g $ha^{-1}$ recorded ` 1.93 per rupee investment which is 14.2% more than the plot where no herbicide was used in the previous crop for controlling weeds.

The present investigation conclusively inferred that although hand weeding twice (20 and 40 DAT) effectively controls all categories of weeds and recorded maximum grain yield of *kharif* paddy but it was statistically at par with the Almix 20% WP treatment which brought about the maximum weed suppression, leading to higher yield of paddy and succeeding lathyrus crop over control. This herbicidal treatment offered slight residual weed control in succeeding lathyrus crop. The herbicide Almix was also found to be non-phytotoxic to rice plant. It did not leave any phytotoxicity to the succeeding crop lathyrus as well. Therefore, the application of Almix 20 WP at 4 g ha^{-1} at 15 DAT may be recommended for better weed management in *kharif* paddy followed by lathyrus in new alluvial zone of West Bengal.

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