International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

IJBSM December 2022, 13(12):1458-1464 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR3230

Research Article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2022.3230

Influence of Rice Herbicides on Weed Growth and Nutrient Removal under Different Tillage in Rice–Yellow Sarson Cropping Sequence

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ABSTRACT

A field experiment was conducted during June–February, 2019–20 and 2020–21 to evaluate the impact of tillage and rice herbicides on weed growth, nutrient removal by weeds and the productivity of residual yellow sarson under rice–yellow sarson cropping. Two tillage system viz. zero tillage (ZT–ZT) and conventional tillage (CT–CT) in main plot and six herbicide combinations [oxadiargyl at 90 g ha^{-1} followed by (fb) bispyribac-sodium at 25 g ha^{-1}, penoxsulam+cyhalofop-butyl at 180 g ha^{-1}, oxadiargyl at 90 g ha^{-1} fb penoxsulam+cyhalofop-butyl at 180 g ha^{-1}, fenoxaprop-p-ethyl+ethoxysulfuron at 90+15 g ha^{-1}, oxadiargyl at 90 g ha^{-1} fb fenoxaprop-p-ethyl+ethoxysulfuron at 90+15 g ha^{-1} and pendimethalin at 1000 g ha^{-1} fb bispyribac-sodium at 25 g ha^{-1}] along with unweeded and weed free check were assigned in sub plot in rice. Under ZT–ZT, the nutrient removal by weeds was found to be less, while, yellow sarson removed (uptake) greater amount of nutrients besides producing better growth attributes and yield as compared to those under CT–CT. Zero tillage (ZT–ZT) recorded 37.0 and 37.3% higher seed and stick yield of yellow sarson as compared to CT–CT. The herbicides applied in rice had no carryover effect on the growth and yield of the yellow sarson. However, oxadiargyl fb fenoxaprop-p-ethyl+ethoxysulfuron and oxadiargyl fb penoxsulam+cyhalofop-butyl were found to be better to control weeds in rice (92-95% Weed control efficiency) compared to other herbicide combinations (21–91%). Hence, the ZT–ZT system with oxadiargyl at 90 g ha^{-1} fb fenoxaprop-p-ethyl+ethoxysulfuron at 90+15 g ha^{-1} and oxadiargyl at 90 g ha^{-1} fb penoxsulam+cyhalofop-butyl at 180 g ha^{-1} appeared to be the best option for managing weeds, reducing nutrient loss and obtaining higher yield of yellow sarson under rice–yellow sarson sequence.

KEYWORDS: Herbicide, nutrient removal, rice, tillage, yellow sarson

Citation* (VANCOUVER)*: Jaiswal et al., Influence of Rice Herbicides on Weed Growth and Nutrient Removal under Different Tillage in Rice–Yellow Sarson Cropping Sequence. *International Journal of Bio-resource and Stress Management,* 2022; 13(12), 1458-1464. HTTPS://DOI.ORG/10.23910/1.2022.3230.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 18th August 2022 RECEIVED in revised form on 20th November 2022 ACCEPTED in final form on 04th December 2022 PUBLISHED on 20th December 2022

1. INTRODUCTION

Rice (*Oryza sativa* L.)–yellow sarson (*Brassica campestris* L var. yellow sarson) is an important cropping system that is widely followed by farmers in the Indo–Gangetic Plains (IGP). Rice is grown in an area of 43.6 mha 118.8 mt accounting for 39.9% of total food grain production in India. The area of rapeseed–mustard is 6.7 mha with a production of 9.1 mt (27.2% of total oilseed production) (Anonymous, 2020).

The most common practice of growing rice is transplanting of seedlings in puddled soil (Chauhan, 2012, Mahajan et al., 2012). Intensive tillage in wet conditions referred to as puddling, consumes large amount of water (Bouman and Tuong, 2001) and affects the soil health due to dispersion of soil particles, increase the soil compaction and makes tillage operations difficult for succeeding crop requiring more energy (Chhokar et al., 2007). The share of agriculture's water is declining because of increasing domestic and industrial use of water (Kumar and Ladha, 2011). Because of farm labor and irrigation water shortage, farmers in some Asian countries are taking interest in dry direct–seeded rice systems (Mahajan et al., 2013). In addition to saving labor and water, direct–seeded rice (DSR) improves the soil's physical and chemical properties, which facilitate the growth and yield of non–rice crops grown in rotation with rice (Gathalaet al., 2011, Singh et al., 2014). Rice that is grown under direct seeding can be harvested earlier, which enables earlier sowing of the crop that comes after it.

Despite the numerous benefits of DSR, weed management is a major barrier to the system's success (Rao et al., 2007, Mandal et al., 2011). Herbicides which are very efficient and cost–effective tools, are being used frequently to manage weeds in rice–growing areas due to labour shortage (Singh et al., 2016, Verma et al., 2016, Nagarjun et al., 2019). Herbicide residue in the soil affects the growth of succeeding crops (Malik and Duary 2013, Upasani et al., 2017a, Mondal et al., 2019). Therefore, the selection of an herbicide must be based on the prevalent cropping pattern in that region. Herbicides that are used in the preceding crop will have a residual effect on the growth of weeds in the succeeding crop (Verma et al., 2009, Gangireddy and Subramanyam, 2020, Kumar et al., 2020, Sathyapriya and Chinnusamy, 2020). Tillage practices have an impact on the vertical distribution of weed seeds (Singh et al., 2015). This, in turn causes a shift in the dynamics of the weed population (Buhler, 1991, Upasani et al., 2017b). Factors such as seed burial depth, soil moisture and light affect the germination and emergence of weed seed (Chauhan and Johnson, 2008a&b, Chauhan and Johnson, 2009). Weeds are more efficient in removing nutrients from the soil than crops (Blackshaw et al., 2003), which lowers agricultural yield. Herbicides suppress the growth of weeds, allowing crops to absorb more nutrients. However, limited information is available on weed growth and nutrient removal by weed under different tillage and herbicide combination applied in rice on succeeding crop. The objective of the present investigation was to study the effect of combined/sequential application of herbicides applied in rice on nutrient removal by weeds and crop uptake under different tillage practices in succeeding yellow sarson.

2. MATERIALS AND METHODS

2.1. Experimental period and location

A field study was conducted for two consecutive years [rice in *kharif* (June–October) 2019 and 2020; yellow sarson in *rabi* (November–February) 2019–20 and 2020–21] in a fixed plot. The field study was conducted at the Agricultural Farm of Institute of Agriculture, Visva–Bharati University, in West Bengal, India. The field is geographically located at about 23°40'09''N latitude and 87°39'30''E longitude with an average altitude of 81 m above the mean sea level of sub–humid red lateritic agro–ecological zone of the tropics. The soil of the experiment field was sandy loam (*Ultisol*) in texture, slightly acidic in reaction with pH 5.8, medium in organic carbon (0.6%), low in available N (253.0 kg ha^{-1}), medium in available P (19.0 kg ha^{-1}) and medium in available K (135.0 kg ha^{-1}).

2.2. Experimental design and treatments details

The experiment was conducted in a split–plot design, with two tillage systems [zero tillage both in rice and yellow sarson (ZT–ZT) and conventional tillage both in rice and yellow sarson (CT–CT) in the main plot and six chemical weed management [pre–emergence application (PE) of oxadiargyl (Topstar 80 WP) at 90 g ha^{-1} followed by (fb) post–emergence application (PoE) of bispyribac-sodium (Nominee Gold 10 SC) at 25 g ha^{-1}, penoxsulam+cyhalofop-butyl (Vivaya 6 OD) (ready–mix) PoE at 180 g ha^{-1}, oxadiargyl at 90 g ha^{-1} fb penoxsulam+cyhalofop-butyl at 180 g ha^{-1}, fenoxaprop–p–ethyl (Ricestar 6.9 EC)+ethoxysulfuron (Sunrice 15 WGD) (tank–mix) PoE at 90+15 g ha^{-1}, oxadiargyl at 90 g ha^{-1} fb fenoxaprop-p-ethyl+ethoxysulfuron at 90+15 g ha^{-1}, pendimethalin (Dhanutop 30 EC) PE at 1000 g ha^{-1} fb bispyribac-sodium at 25 g ha^{-1}] and two control (unweeded and weed free check) in the sub plot, which were replicated thrice.

2.3. Package and practices

For conventional sowing of rice and yellow sarson, land preparation was done using a rotavator. In ZT–ZT plots, there was no primary tillage at all. Rice was planted using a zero till ferti-cum-seed drill machine in the last week of June 2019 and 2020. For the seeding of yellow sarson, ZT–ZT areas were left undisturbed. In both the ZT–ZT and CT–CT plots, yellow sarson sowing was done manually just opening the small furrow with wrinkle type small spade placing fertilizer in lower layer and seeds in upper layer in continuous line at 30 cm row to row spacing without disturbing the layout in second week of November. Subsequently, thinning operation was done at 15 DAS to maintain plant to plant distance of 10 cm. Before seeding rice and yellow sarson, herbicide (glyphosate at 1.0 kg ha^{-1}) was applied to suppress weeds in ZT–ZT plots. All the herbicides were applied in rice with a battery–operated knapsack sprayer equipped with a flat fan nozzle with a spray volume of 500 litres ha^{-1}. No weed management practices were followed in the residual crop yellow sarson. The rice cultivar "MTU-1010" and yellow sarson cultivar "B–9" was used as a test crop. Both rice and yellow sarson was fertilized with 80:40:40 kg ha^{-1} of N:P_2O_5:K_2O, respectively. The gross and net plot size of the sub-plots were 5×4.5 m^2 and 3×3 m^2, respectively.

2.4. Observations and procedure of nutrient analysis

Observations on weeds were recorded by placing the quadrat of size 50×50 cm^2 at 60 DAS. The values were converted to express the density in number of weeds m^{-2}. Weeds were cleaned by washing, kept in sunlight for few hours and were kept in a hot air oven for drying at 70°C for 72 hours or more till constant weights were recorded. The values of weed biomass were converted to express the biomass of weeds g m^{-2}.

Samples were dried in a hot air oven at 70°C for 48 hours before chemical analysis. Total nitrogen was estimated using the Kjeldahl method from acid digestion, total phosphorus was estimated using the Vanado molybdate yellow colour method from diacid extract and total potassium was estimated using the flame photometric method from diacid extract as suggested by Jackson (1973). The uptake of nitrogen (N), phosphorus (P) and potassium (K) by crops and removal by weeds was estimated by multiplying crop yield/weed biomasss with the corresponding % composition of N, P and K.

2.5. Methods of statistical analysis

Weed data were subjected to square root [√X+0.5] transformation and the transformed data was used for analysis. Statistical analysis of the data was done as described by Gomez and Gomez (1984) at a 5% level of significance (polled analysis). The original data have been given in parentheses in each table along with the transformed values.

3. RESULTS AND DISCUSSION

3.1. Weeds in experimental site and their nutrient content

The yellow sarson field was infested with *Digitaria sanguinalis* (L.) Scop., *Polygonum plebeium* (R. Br.) and *Gnaphalium indicum* (L.). Out of these weeds *D. sanguinalis* was common weed of previous crop rice and residual crop yellow sarson. Duary et al. (2015) and Teja and Duary (2018) also reported similar type of weeds in yellow sarson in this region.

3.2. Effect of tillage on weed density, biomass and weed nutrient removal in succeeding yellow sarson

Residual crop yellow sarson under ZT–ZT, registered 63.5 and 58.9% lower total weed density and biomass, respectively over yellow sarson under CT–CT (Table 1). Glyphosate was used to kill weeds that had emerged in a ZT–ZT system prior to sowing of both rice and yellow sarson. Glyphosate in zero tillage systems did not allow weeds to recharge seedbank in between crop season (Chauhan, 2012, Nandan et al., 2020). And this could be the reason for low infestation of weed in ZT–ZT in current study. Pratibha et al. (2021) reported similar results in zero tillage with glyphosate. On the other side use of rotavator buried the emerged population of weed in CT–CT system and also exposed the viable dormant seeds on to the surface. Tillage stimulates weed emergence as buried seeds exposed to light (Chauhan, 2012). Higher infestation of weeds in mustard in conventional tillage than zero tillage under rice–mustard cropping system was earlier reported by Das et al. (2020). Nutrient (N, P and K) removal by weeds was greater in yellow sarson under CT–CT (by 58.0, 58.3 and 59.5%, respectively) due to the higher biomass of weeds in CT–CT as compared ZT–ZT. As previously reported by Kumari et al. (2016), Patel et al. (2018) and Sen et al. (2021) nutrient removal by weed increased with increase in weed biomass.

3.3. Effect of rice herbicides on weed density, biomass and weed nutrient removal in succeeding yellow sarson

The removal of nutrients (N, P and K) by weeds in residual crop was highest under unweeded control compared to plot treated with rice herbicides (Table 1), except for the plot that had been treated with ready–mix penoxsulam+cyhalofop-butyl alone possibly due to poor control of weed in previous crop rice (Figure 1). This was due to the higher weed biomass in unweeded control plots. The herbicides applied in rice significantly reduced the density of total weed in succeeding crop to the tune of 5.9–29.0%. This is mainly because of efficacy of herbicides in reducing the weed population thus weed seed bank (Verma et al., 2009, Sathyapriya and Chinnusamy, 2020), thus reduced the infestation of weed in succeeding crop (Gangireddy and Subramanyam, 2020). This might be due to weed free environment as a result of carryover effect of herbicides on succeeding crop (Kumar et al., 2020).

3.4. Effect of tillage on growth of succeeding yellow sarson

At harvest, the number of plants in CT–CT was 13.5% lower than in the ZT–ZT (Table 2). Similarly, significantly

Table 1: Weed density, weed biomass and nutrient removal by weeds at 60 DAS in yellow sarson under different tillage and weed management practices

Treatment	Weed density (No m^{-2})	Weed biomass (g m^{-2})	Nutrient removal (kg ha^{-1})		
			N	P	K
Tillage practices					
Zero tillage (ZT–ZT)	17.60 (309)	8.32 (69)	11.7	1.0	11.8
Conventional tillage (CT–CT)	29.11 (847)	12.99 (168)	27.9	2.4	29.2
SEm±	0.41	0.23	0.7	0.1	0.8
CD (*p*=0.05)	2.52	1.39	4.6	0.4	4.7
Weed management practices					
Oxadiargyl fb bispyribac-sodium	22.38 (500)	10.41 (108)	18.5	1.6	20.5
Penoxsulam+cyhalofop-butyl	24.35 (592)	12.14 (147)	24.6	2.1	25.5
Oxadiargyl fb penoxsulam+cyhalofop-butyl	23.84 (568)	10.24 (104)	18.4	1.6	19.1
Fenoxaprop-p-ethyl+ethoxysulfuron	22.08 (487)	10.16 (103)	18.7	1.6	19.4
Oxadiargyl fb fenoxaprop-p-ethyl+ethoxysulfuron	21.15 (447)	8.94 (79)	14.6	1.3	15.8
Pendimethalin fb bispyribac-sodium	23.94 (573)	10.96 (120)	20.7	1.8	20.4
Weed free check	23.97 (574)	10.63 (112)	19.5	1.7	18.3
Unweeded control	25.10 (629)	11.76 (138)	23.4	2.0	25.1
SEm±	0.64	0.36	1.2	0.1	1.1
CD (*p*=0.05)	6.75	0.67	3.6	0.3	3.2

*Figures within parentheses indicate original values and the data were transformed to √(X+0.5) before analysis

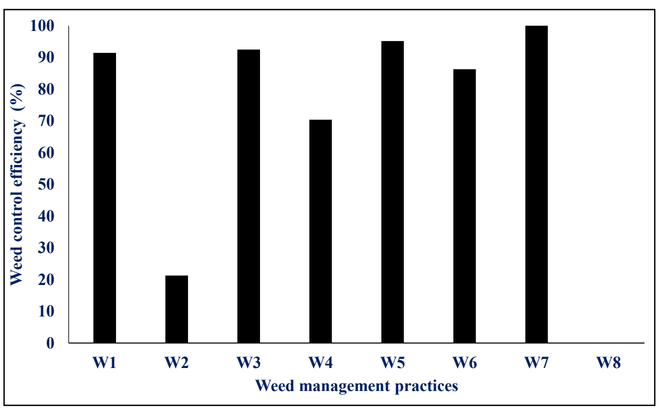

Figure 1: Weed control efficiency of herbicides applied in direct–seeded rice; W_1: Oxadiargyl fb bispyribac-sodium; W_2: Penoxsulam+cyhalofop-butyl; W_3: Oxadiargyl fb penoxsulam+cyhalofop-butyl; W_4: Fenoxaprop-p-ethyl+ethoxysulfuron; W_5: Oxadiargyl fb fenoxaprop-p-ethyl+ethoxysulfuron; W_6: Pendimethalin fb bispyribac-sodium; W_7: Weed free check; W_8: Unweeded control

higher value of plant height and number of siliqua plant^{-1}of residual crop yellow sarson was with ZT–ZT, compared to CT–CT due to suppression of crop growth following heavy infestation by weeds under latter treatment (Table 1). However, number of seeds siliquae^{-1} and test weight of yellow sarson didn't vary significantly between tillage practices. Under conventional tillage, nutrient availability for yellow sarson growth was limited as weeds under CT–CT removed greater amount of N (27.9 kg ha^{-1}), P (2.4 kg ha^{-1}) and K (29.2 kg ha^{-1}) as compared to that of ZT–ZT (N: 11.7 kg ha^{-1}; P: 1.0 kg ha^{-1} K: 11.8 kg ha^{-1}).

Among weed management practices fenoxaprop–p–ethyl and oxadiargyl fb fenoxaprop–p–ethyl recorded the highest number of siliqua plant^{-1}. However, the herbicides had no significant effect of plant population, plant height, number of seeds siliquae^{-1} and test weight of yellow sarson.

3.5. Effect of tillage on nutrient uptake and yield of succeeding yellow sarson

Residual crop under ZT–ZT system recorded higher nutrient uptake [N (54.7 vs 34.4 kg ha^{-1}), P (18.5 vs 11.6 kg ha^{-1}) and K (35.0 vs 22.0 kg ha^{-1})] than under CT–CT system (Table 2). There was a negative linear relationship with nutrient removal by weeds and nutrient uptake by the crop with co–efficient of determination of 0.8018, 0.7897 and 0.8184 for N, P and K, respectively (Figure 2, 3 and 4). It indicates that crop nutrient uptake decreased as weed nutrient removal increased. We also observed higher SPAD reading of yellow sarson leaf under ZT–ZT system than under CT–CT by 19.2% (Table 2). This might be because higher uptake and lower removal of N under ZT–ZT than under CT–CT, since nitrogen is an essential component

Table 2: Plant population, growth and yield parameters, yield and nutrient uptake of residual yellow sarson under different tillage and weed management practices

Treatment	PP	PH	NSP	NSS	TW	Yield (kg ha^{-1})		Nutrient uptake (kg ha^{-1})		
						Seed	Stick	N	P	K
Tillage practices										
Zero tillage (ZT–ZT)	37	112	109	21	3.09	1347	3261	54.7	18.5	35.0
Conventional tillage (CT–CT)	32	94	60	21	3.04	848	2044	34.4	11.6	22.0
SEm±	1	1	2	0.3	0.02	8	27	0.2	0.1	0.1
CD (p=0.05)	4	6	12	2	0.13	50	165	1.4	0.5	0.9
Weed management practices										
Oxadiargyl fb bispyribac-sodium	33	103	83	21	3.12	1065	2506	42.9	14.5	27.4
Penoxsulam+cyhalofop-butyl	35	105	81	21	3.12	1093	2562	44.0	14.9	28.0
Oxadiargyl fb penoxsulam+cyhalofop-butyl	33	104	83	20	3.16	1097	2698	44.8	15.2	28.7
Fenoxaprop-p-ethyl+ethoxysulfuron	33	103	94	22	2.99	1157	2814	47.0	15.9	30.1
Oxadiargyl fb fenoxaprop-p-ethyl+ethoxysulfuron	36	101	92	20	3.03	1159	2680	46.4	15.7	29.6
Pendimethalin fb bispyribac-sodium	33	102	82	20	3.01	1082	2722	44.5	15.1	28.6
Weed free check	37	102	82	21	3.08	1085	2679	44.3	15.0	28.4
Unweeded control	35	103	83	21	3.01	1042	2556	42.5	14.4	27.2
SEm±	1	1	3	1	0.08	33	83	1.2	0.4	0.7
CD (p=0.05)	4	4	9	2	0.22	95	239	3.4	1.1	2.2

PP: Plant population (No. m^{-2}) at harvest; PH: Plant height (cm) at harvest; NSP: No. of siliqua plant^{-1}; NSS: No. of seeds siliquae^{-1}; TW: Test weight (g)

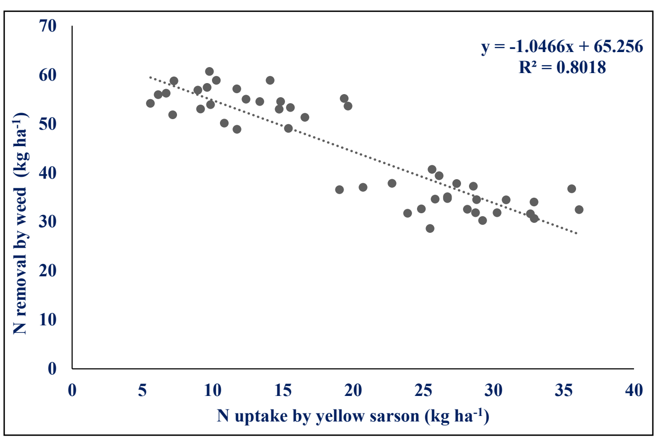

Figure 2: The relationship between N removal by weed and N uptake by yellow sarson

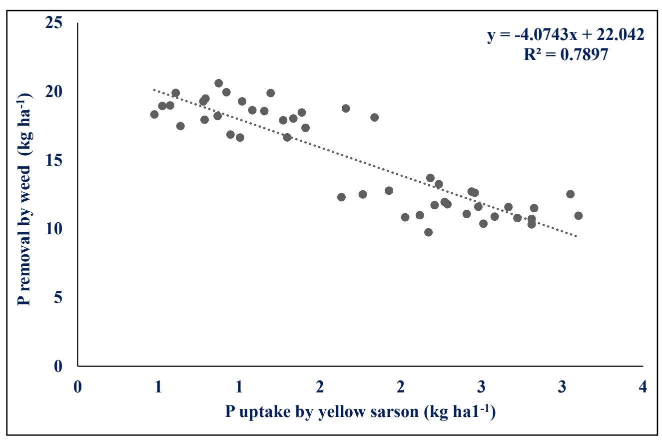

Figure 3: The relationship between P removal by weed and P uptake by yellow sarson

of chlorophyll. And therefore, higher seed and stick was in ZT–ZT sown yellow sarson than sown under CT–CT by 37.0 and 37.3%, respectively.

3.6. Effect of herbicides on nutrient uptake and yield of succeeding yellow sarson

Among the herbicides applied in rice, namely oxadiargyl fb fenoxaprop-p-ethyl+ethoxysulfuron and fenoxaprop-p-ethyl+ethoxysulfuron recorded the highest seed yield (1159 and 1157 kg ha^{-1}, respectively) of residual crop yellow sarson, having no significant difference from other herbicide combinations, unweeded control and weed free check. The SPAD reading was statistically the same under all weed management practices (Table 2), which indicates that rice herbicides had no significant effect on nutrient uptake and

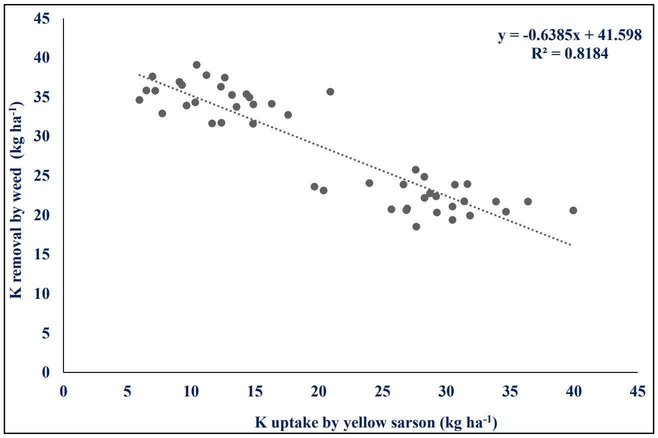

Figure 4: The relationship between K removal by weed and K uptake by yellow sarson

therefore the final yield of residual crop. Our findings were also consistent with those of Punia et al. (2016), Singh et al. (2017) and Mondal et al. (2019).

4. CONCLUSION

Zero tillage system with oxadiargyl fb fenoxaprop-p-ethyl+ethoxysulfuron and oxadiargyl fb penoxsulam+cyhalofop-butyl appeared to be a promising option for managing weeds, reducing nutrient loss and obtaining higher yield of yellow sarson under rice–yellow sarson sequence. Zero tillage system with pendimethalin fb bispyribac-sodium was the next best treatment.

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