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RESEARCH ARTICLE

Weed density, growth performance and nutrient uptake of basmati rice as affected by weed control measures under direct seeding

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Abstract

Weed infestation is one of the major constraints limiting the productivity of direct seeded rice (DSR) and there is a need for sustainable and eco-friendly management options beyond sole reliance on herbicides. A field experiment was conducted during the Kharif season of 2022 at the Research Farm, Chatha, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, to evaluate the effect of different weed management practices on growth parameters, weed density and nutrient uptake by weeds under direct seeded basmati rice. The experiment was laid out in a randomized block design with three replications on sandy loam soil. The results revealed that the weed-free treatment was significantly superior in enhancing crop growth parameters, followed by mechanical weeding using a cono-weeder at 20 and 40 days after sowing (DAS). Among the leguminous mulches used as a weed management strategy, surface mulching with dhaincha (*Sesbania aculeata*) through cutting was the most effective, significantly improving growth parameters over other mulching treatments. Weed density and nutrient uptake by weeds were significantly reduced in treatments involving mechanical weeding twice at 20 and 40 DAS and in surface mulching with cut dhaincha. The study demonstrated that while conventional weed control methods like mechanical weeding and herbicide application remain effective for DSR, alternative eco-friendly approaches such as using leguminous cover crops like dhaincha, especially when cut and used as surface mulch, can also play a substantial role in suppressing weed growth and conserving nutrients for the rice crop. These findings highlight the potential of integrating leguminous mulching strategies into sustainable weed management practices for enhancing DSR productivity.

Keywords: direct seeded rice; dhaincha; leguminous mulch; mechanical weeding; nutrient uptake; weed management

Introduction

Aromatic basmati rice in India has got the special attention from the consumers due to its pleasure aroma, while it is gaining popularity among the cultivators due to the premium price. Out of the emerging rice cultivation practices, direct- seeded rice (DSR) is a sustainable rice production system because it requires 60 % less labour and produces rice with lower methane emissions and water usage (1, 2). Among the various factors causing crop production losses, weeds contribute approximately 34 %. But in DSR, the losses can increase upto 60 % due to lack of suitable and appropriate weed control practice (3). Control of weeds through herbicides has resulted in substantial load in the crop/soil and weed resistance has also emerged as a problem (4).

Previous studies have shown that cultural approaches such as mechanical weeding, mulching and inclusion of cover crops can significantly reduce weed density and improve rice growth under direct seeded rice systems. In particular, legumes like Sesbania and cowpea have been reported to suppress weeds through their rapid canopy coverage and allelopathic effects, while also contributing to soil fertility. Mulching with cut dhaincha or its incorporation as brown manuring has been highlighted as a potential low-cost, eco-friendly practice that can conserve soil nutrients and reduce dependence on herbicides (5).

Leguminous crops due to its better canopy and allelopathic characteristics can be used for reducing weed infestation along with the lowering of the production cost (6). Thus, the current study was carried out with the aim of managing weeds in an environmentally sustainable way through concurrent cultivation of rice and legumes as surface mulches and subsequent incorporation of legumes by cutting or brown manuring.

Materials and Methods

Research Farm of the Division of Plant Breeding and Genetics (PBG), Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu served as the site of the field experiment in the Kharif, 2022. The location of the experiment is at an altitude of 332 metres above mean sea level and is situated at 32° 40′N" and 74°58′E". Over the course of the study, there was 1021 mm of rainfall and the highest and lowest temperatures were 37.60 °C and 24.5 °C, respectively. The texture of the soil was sandy clay loam with EC of 0.22 dS/m and a pH of 7.84, which is slightly alkaline. The soil had low levels of organic carbon (4.60 g/kg) and available nitrogen (246.15 kg/ha), but medium levels of potassium (44.36 kg/ha) and phosphorus (146.28 kg/ha), respectively as estimated by standard methods (7-10).

Fourteen different weed management treatment combinations underwent evaluation using three replications and a randomised block design showed in Table 1. For treatments (chemical weed control through pyrazosulfuron and bispyribacsodium, weed free and weedy check), direct sowing of variety Jammu Basmati-123 was carried out using a seed rate of 30 kg per hectare at 20 cm row to row distance. The remaining treatments, a seed rate of 25 kg per hectare with 25 cm row to row spacing was employed. On the same day, the legume crops that were mulched between two rows of rice to suppress weeds were also sown at the seed rate of 15 kg/ha for cowpea, 30 kg/ha for dhaincha, 25 kg/ha for sunhemp, 10 kg/ha for green gram and 10 kg/ha for black gram. At 30 days after sowing (DAS), cutting operations and brown manuring with 2, 4-D at the concentration of 500 g per hectare were carried out to incorporate leguminous crops into the soil.

In chemical weed control treatment (CWCPBS), pyrazosulfuronat 25 g/ha used as pre-emergence and bispyribac sodium at 25 g/ha used as post-emergence herbicide for controlling weeds. Whereas, in weed free treatment, weeds were controlled through hand weeding as and when required. Mechanical weeding (MW) with a cono-weeder was carried out at 20 and 40 DAS. In accordance with the package of practices urea, di-ammonium phosphate and muriate of potash were used to apply the recommended dose of NPK (34:24:14 kg/ha). Weed samples were collected by using quadrant (1 m × 1 m) and then converted into number/m^2 (11). To normalise the distribution of the weed density data, a square root transformation was applied (12). Relative weed density, leaf area index and nutrient uptake by weeds was calculated as per the standard formulas (13, 14).

$$\text{RWD (\%)} = \frac{\text{Absolute density of individual species}}{\text{Total number of all weed species}} \times 100 \qquad \text{(Eqn. 1)}$$

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area per plant (cm}^2\text{)}} \qquad \text{(Eqn. 2)}$$

$$\text{Land area per plant} = \text{Row distance x plant distance} \qquad \text{(Eqn. 3)}$$

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x dry matter accumulation (kg ha}^{-1}\text{)}}{100} \qquad \text{(Eqn. 4)}$$

The F-test was used in an analysis of variance to analyse the data and the least significant difference method was used to compare treatment means at $p = 0.05$. The software/package used for analysis of variance (ANOVA) and LSD were SPSS, statistics version 26.0 and OPSTAT.

Table 1. Treatment details

T_1	Surface mulching with dhaincha by cutting (SMDC)
T_2	Surface mulching with dhaincha by brown manuring (SMDBM)
T_3	Surface mulching with sunhemp by cutting (SMSC)
T_4	Surface mulching with sunhemp by brown manuring (SMSBM)
T_5	Surface mulching with cowpea by cutting (SMCC)
T_6	Surface mulching with cowpea by brown manuring (SMCBM)
T_7	Surface mulching with green gram by cutting (SMGC)
T_8	Surface mulching with green gram by brown manuring (SMGBM)
T_9	Surface mulching with black gram by cutting (SMBC)
T_{10}	Surface mulching with black gram by brown manuring (SMBBM)
T_{11}	Mechanical weeding twice at 20 and 40 DAS (MW)
T_{12}	Pyrazosulfuron 25 g ha^{-1} at 0-3 DAS followed by bispyribac sodium at 25 mL ha^{-1} at 25-30 DAS (CWCPBS)
T_{13}	Weed free (WF)
T_{14}	Weedy check (WC)

Results and Discussion

Growth parameters

Different combinations of weed management had a significant impact on crop growth parameters, including plant height at harvest, leaf area index at 90 DAS, crop growth rate (CGR) at 60-90 DAS and number of tillers at harvest and the relevant data presented in Table 2. Weed free treatment (WF) yielded the significantly taller plant and mechanical weed control (MW) was the subsequent treatment. Under weedy check (WC), the shortest plant height was recorded. Growth parameters, namely the number of tillers, crop growth rate and leaf area index, showed similar trend. Eliminating weeds reduced competition, improving resource utilization by the crop. Additionally, it was discovered through research that mechanical weeding with rotating hoes and tiny toothed wheels increased soil pores, made it easier for roots and microorganisms to obtain oxygen and significantly aided in the development of tillers (15-17). Amongst, leguminous mulches applied for weed control purpose noticeably higher values of growth parameters were observed in surface mulching with dhaincha by cutting (SMDC). The increased biomass production of the dhaincha crop, which increases the availability of N and other micronutrients through subsequent incorporation, was found to be the cause of the higher values of growth parameters with this treatment (18, 19).

Weed parameters

A variation in weed species density compared to the weedy check was observed across treatments at 60 DAS. Since no weeds were permitted to grow in weed-free plots, the weed density was 100 % lower in the weed-free treatment than in the weedy check. Plots where weeds were left to compete with the rice crop without any weed management practices, such as weed check, showed the lowest percentage of reduction in weed density. Mechanical weeding (MW) had the lowest density of all the weed species which was followed by pyrazosulfuron at a concentration of 25 g per hectare at 0-3 DAS, followed by bispyribac sodium at a concentration of 25 mL per hectare at 25-

Table 2. Effect of weed management approaches on crop growth parameters in direct-seeded basmati rice

Treatments	Plant height (cm)	Leaf area index	Crop growth rate (g m^{-2} day^{-1})	No. of tillers (m^{-2})
	At harvest	90 DAS	60 -90 DAS	At harvest
Surface mulching with dhaincha by cutting (SMDC)	144.2	3.5	7.8	277.0
Surface mulching with dhaincha by brown manuring (SMDBM)	139.0	3.2	7.4	256.0
Surface mulching with sunhemp by cutting (SMSC)	141.7	3.4	7.6	266.0
Surface mulching with sunhemp by brown manuring (SMSBC)	136.0	3.1	7.2	245.0
Surface mulching with cowpea by cutting (SMCC)	144.0	3.4	7.7	276.0
Surface mulching with cowpea by brown manuring (SMCBM)	138.2	3.2	7.4	254.0
Surface mulching with green gram by cutting (SMGC)	141.1	3.4	7.6	268.0
Surface mulching with green gram by brown manuring (SMGBM)	137.6	3.1	7.3	247.0
Surface mulching with black gram by cutting (SMBC)	142.2	3.4	7.6	271.0
Surface mulching with black gram by brown manuring (SMBBM)	137.3	3.1	7.3	249.0
Mechanical weeding twice at 20 and 40 DAS (MW)	151.6	3.8	8.8	289.0
Pyrazosulfuron 25 g ha^{-1} at 0-3 DAS followed by bispyribac sodium at 25 mL ha^{-1} at 25-30 DAS (CWCPBS)	146.6	3.6	8.1	279.0
Weed free (WF)	156.8	3.9	8.7	298.0
Weedy check (WC)	102.0	2.7	5.9	134.0
S.E.m(±)	1.67	0.05	0.09	1.77
L.S.D. (p = 0.05)	5.01	0.15	7.8	5.32

30 DAS (Table 3). Since it uproots and buries weeds in the soil during the first flush, it effectively controls weeds, resulting in a significantly lower weed density.

Lower number of weeds and their dry biomass were recorded under the herbicidal application was due to sequential application of weedicides leading to extended period of weed control. Pre-emergence application of herbicides pyrazosulfuron lowered down the initial flushes of weeds significantly and bispyribac has been reported very effective against mixed flora of weeds which could be witnessed at 60 DAS and thereafter (20, 21). Amongst, leguminous mulching surface mulching with dhaincha by cutting (SMDC) recorded significantly lower weed density. The legume crops gave more effective control of weeds present in topsoil layer, by producing allelo-chemicals or ground cover. Higher biomass incorporation of dhaincha suppresses the mixed weed flora by both stimulatory and inhibitory effects because aqueous leaf extracts of *Sesbania* contain allelo-chemicals such as phenols, tannins, sterols and saponins that aid in reducing weed growth and germination (22, 23). Methods of incorporation showed significant variation on weed density and dry matter. Studies revealed that broad-leaved weeds were effectively controlled by *Sesbania* broadcast at 25 kg seed per hectare with rice and burned down by the application of 2,4-D ester at 500 g per hectare 30 DAS, but grasses and sedges were uncontrollable (6).

Table 3. Effect of weed management approaches on weed density in direct-seeded basmati rice

Treatments	Weed density (no. m^{-2})					
	***Echinochloa* spp.**	***Dactyloctenium aegyptium***	***Cynodon dactylon***	***Cyperus* spp.**	***Caseullia axillaries***	**Other weeds**
T_1- surface mulching with dhaincha by cutting (SMDC)	2.3 (4.2)	2.1 (3.3)	2.3 (4.2)	2.5 (5.3)	2.0 (2.8)	1.9 (2.7)
T_2- surface mulching with dhaincha by brown manuring (SMDBM)	3.47 (10.3)	3.0 (8.2)	3.0 (8.2)	3.9 (14.0)	1.0 (0.0)	2.4 (4.7)
T_3- surface mulching with sunhemp by cutting (SMSC)	3.1 (8.8)	3.1 (8.5)	2.8 (7.0)	3.3 (10.2)	2.5 (5.0)	2.3 (4.2)
T_4- surface mulching with sunhemp by brown manuring (SMSBM)	4.0 (15.0)	3.3 (10.2)	3.9 (14.1)	4.4 (18.7)	1.0 (0.0)	3.1 (8.2)
T_5- surface mulching with cowpea by cutting (SMCC)	2.6 (5.7)	2.5 (5.0)	2.3 (4.3)	2.7 (6.3)	2.1 (3.3)	1.9 (2.7)
T_6- surface mulching with cowpea by brown manuring (SMCBM)	3.6 (11.8)	3.1 (8.3)	3.2 (9.1)	4.0 (15.0)	1.0 (0.0)	2.5 (5.3)
T_7- surface mulching with green gram by cutting (SMGC)	3.0 (7.8)	2.8 (7.0)	3.0 (7.8)	3.2 (9.3)	2.3 (4.5)	2.2 (4.0)
T_8- surface mulching with green gram by brown manuring (SMGBM)	3.9 (14.2)	3.3 (10.0)	3.9 (13.8)	4.1 (16.2)	1.0 (0.0)	3.0 (8.0)
T_9- surface mulching with black gram by cutting (SMBC)	2.7 (6.5)	2.6 (5.5)	2.6 (6.0)	3.2 (9.3)	2.2 (3.8)	2.2 (4.0)
T_{10}-surface mulching with black gram by brown manuring (SMBBM)	3.8 (13.3)	3.2 (9.3)	3.5 (11.2)	4.0 (14.7)	1.0 (0.0)	2.8 (7.0)
T_{11}-mechanical weeding twice at 20 and 40 DAS (MW)	1.5 (1.3)	1.4 (1.0)	1.5 (1.3)	2.2 (3.8)	1.5 (1.2)	1.0 (0.0)
T_{12}- pyrazosulfuron 25 g ha^{-1} at 0-3 DAS followed by bispyribac sodium at 25 mL ha^{-1} at 25-30 DAS (CWCPBS)	2.1 (3.5)	1.8 (2.3)	1.9 (2.7)	2.4 (4.7)	1.8 (2.3)	1.8 (2.2)
T_{13}– weed free (WF)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
T_{14}– weedy check (WC)	5.1 (24.7)	4.4 (18.0)	4.6 (20.5)	6.4 (40.0)	3.7 (12.3)	3.7 (12.7)
S.E.m(±)	0.06	0.05	0.06	0.04	0.04	0.03
L.S.D. (p = 0.05)	0.16	0.14	0.19	0.11	0.13	0.09

Among grassy weeds, relative weed density of *Echinochloa* spp. was found to be the most dominant at 30 DAS with 17.0 %, followed by *C. dactylon* (15.73 %) and *D. aegyptium* (9.63 %), respectively. With the advancement in growth stages of basmati rice, density of *Echinochloa* spp. increases upto 60 DAS and thereafter decreases. *C. dactylon* demonstrated a rise in density as rice crop age increased. *D. aegyptium* showed increasing relative weed density from 30 DAS upto 90 DAS to the tune of 9.63 % to 16.13 % thereafter decreases at 120 DAS (16.09 %) and then increases during harvest (16.39 %).

Nutrient uptake

Weeds showed the highest uptake of N, P and K in the weedy check treatment. The likely cause was that there were more weeds in the weedy check treatment than in the other treatment and they were growing quickly and consuming crop nutrients. Weed free treatment (WF) had the lowest nutrient uptake, which was followed by two mechanical weeding treatments at 20 and 40 DAS and herbicidal application of pyrazosulfuron 25 g ha^{-1} at 0-3 DAS. Bispyribac sodium at 25 mL ha^{-1} at 25-30 DAS. Among leguminous mulches lowest nutrient uptake was recorded in surface mulching with dhaincha by cutting because of the low density of weeds in these plots (24, 25). It has been discovered that there is an inverse relationship between the effectiveness of weed control treatments and weed uptake of nutrients. The removal of N, P and K by weeds was restricted in plots treated with herbicides (26). Methods of incorporation showed significant variation on the nutrient uptake by weeds and relevant data is presented in Table 4.

Relative weed density

Relative density of broad-leaved weed *C. axillaries* was gradually decreases from 30 DAS (11.35 %) up to 60 DAS (5.87 %), thereafter increased at 90 DAS (6.06 %) and then decreased up to harvest (5.52 %). Relative densities of *Cyperus* spp. showed decreasing trend from 30 DAS to 90 DAS (36.01 % to 27.59 %), increases at 120 DAS (27.8 %) and then slightly decreases at harvest (27.47 %). In case of other weeds, their relative density was initially increased from 30 DAS (10.26 %) to 60 DAS (10.87 %) and after that it decreased slightly till harvest from (10.87 % to 10.70 %). The relevant data is presented in Table 5.

Conclusion

The study demonstrated that effective weed management is crucial for enhancing the growth and nutrient use efficiency of direct-seeded basmati rice. Weed-free treatment consistently delivered the best performance across all growth parameters, followed closely by mechanical weeding and herbicide application. Among the leguminous mulch treatments, surface mulching with dhaincha (by cutting) proved most effective in reducing weed density and nutrient uptake by weeds, owing to its allelopathic properties and biomass contribution. These findings highlight the potential of integrating leguminous crops, either as surface mulches or through brown manuring, as sustainable and environmentally friendly alternatives to conventional chemical weed control. Future research should focus on evaluating the long-term effects of legume-based mulches on soil health, weed

Table 4. Effect of weed management approaches on nutrient uptake by weeds in direct-seeded basmati rice

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1- surface mulching with dhaincha by cutting (SMDC)	1.6	0.8	1.6
T_2- surface mulching with dhaincha by brown manuring (SMDBM)	5.8	3.2	5.8
T_3- surface mulching with sunhemp by cutting (SMSC)	4.1	2.2	4.1
T_4- surface mulching with sunhemp by brown manuring (SMSBM)	8.1	4.6	8.0
T_5- surface mulching with cowpea by cutting (SMCC)	2.1	1.1	2.1
T_6- surface mulching with cowpea by brown manuring (SMCBM)	6.4	3.5	6.4
T_7- surface mulching with green gram by cutting (SMGC)	3.3	1.7	3.3
T_8- surface mulching with green gram by brown manuring (SMGBM)	7.7	4.3	7.6
T_9- surface mulching with black gram by cutting (SMBC)	3.0	1.6	3.0
T_{10}-surface mulching with black gram by brown manuring (SMBBM)	6.9	3.8	6.8
T_{11}-mechanical weeding twice at 20 and 40 DAS (MW)	1.1	0.6	1.2
T_{12}- Pyrazosulfuron 25 g ha^{-1} at 0-3 DAS followed by bispyribac sodium at 25 mL ha^{-1} at 25-30 DAS (CWCPBS)	1.4	0.7	1.4
T_{13}- weed free (WF)	0.0	0.0	0.0
T_{14}- weedy check (WC)	21.8	12.9	22.8
S.E.m(±)	0.04	0.05	0.08
L.S.D. (p = 0.05)	0.12	0.13	0.24

Table 5. Effect of weed management approaches on relative weed density in direct-seeded basmati rice

Weed species	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Grassy weeds					
Echinochloa spp.	17.0	21.1	21.0	20.9	20.8
Cynodon dactylon	15.7	18.3	18.4	18.8	19.1
Dactyloctenium aegyptium	9.6	16.0	16.1	16.1	16.4
Broad leaved weeds					
Caseullia axillaries	11.4	5.9	6.1	5.6	5.5
Sedges					
Cyperus spp.	36.0	27.8	27.6	27.8	27.5
Others					
Eclipta prostrate, Eleusine indica , Physalis minima, Digitaria sanguinalis	10.3	10.9	10.8	10.8	10.7

seed bank dynamics and crop productivity across multiple seasons. Additionally, integrating such biological weed control strategies with precision agriculture tools-such as site-specific weed mapping, remote sensing and automated decision support systems-could further enhance the efficiency and sustainability of weed management in DSR systems.

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Authors' contributions

AS and MS carried out the field experiment, collection and analysis of data, participated in the sequence alignment and drafted the manuscript. VB participated in the design of the study, supervised the whole research and helped in compiling the manuscript. RK and VK participated in finalization and compiling manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of intere t declare.

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