Peruvian Journal of Agronomy
http://revistas.lamolina.edu.pe/index.php/jpagronomy/index

Received for publication: 26 July 2023
Accepted for publication: 26 August 2023
Published: 30 August 2023
ISSN: 2616-4477

RESEARCH ARTICLE
https://doi.org/10.21704/pja.v7i2.2013

Effect of row spacing and weed management practices on dry direct-seeded spring rice

Efecto de la distancia entre hileras y control de malezas en el cultivo de arroz de primavera de siembra directa en seco

Devraj Sharma Jaishi[1], Rajan Sah[1], Sagar Bhandari[1]* and Santosh Marahatta[2]

[1] Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan, Nepal
[2] Department of Agronomy, Agriculture and Forestry University, Rampur, Chitwan, Nepal

*Corresponding author: sagarbhandari88484@gmail.com
*https://orcid.org/0000-0002-4745-3184

Abstract

Weeds are the major burden for rice-growing farmers in the case of direct-seeded rice due to the preemptive competition of weed in the species early seedling stage. A field experiment was carried out during the spring season in 2021 to evaluate the effect of different weed management practices and row spacing on dry directed-seeded spring rice under the Prime Minister Agriculture Modernization Project (PMAMP) at Rice Super Zone, Kanchanpur, Nepal. The experiment was laid out in a two-factorial randomized complete block design (RCBD) with twelve treatments and three replications. The highest number of effective tillers per m^2 was obtained in weed-free plots (531.67), which is statistically similar to Pretilachlor *fb* 1HW (505.42). Row spacing of 10 cm showed a significantly higher number of effective tillers per square meter (521.94). A higher grain yield was observed in weed-free plots (6397.87 $kg.ha^{-1}$), which is followed by Pretilachlor *fb* 1HW, which is statistically similar to other management practices except for weed check. All the management practices were found effective in reducing weed parameters such as weed density, weed dry weight, and weed index as compared to weed checks. A positive relation was recorded between plant height at 90 DAS and grain yield, thousand-grain weight, and grain yield, and a negative relation was recorded between weed density, weed dry biomass, and grain yield. It is recommended to apply Pretilachlor *fb* 1HW with 10 cm row spacing for effective weed control and to increase the yield of dry direct-seeded rice.

Keywords: *Dry-DSR, Weed density, Weed index, Yield, Nepal*

Resumen

En el caso del arroz de siembra directa, las malezas son la principal carga para los agricultores debido a la competencia preventiva de las malas hierbas en la fase de plántula temprana de la especie. Se llevó a cabo un experimento de campo durante la temporada de primavera de 2021 para evaluar el efecto de diferentes prácticas de manejo de malezas y espaciamiento entre hileras en arroz de primavera de siembra directa en seco bajo el Proyecto de Modernización de la Agricultura del Primer Ministro (PMAMP) en Rice Super Zone, Kanchanpur, Nepal. El experimento se organizó en un diseño de bloques completos aleatorizados de dos factores con doce tratamientos y tres repeticiones. El mayor número de macollos efectivos por m^2 se obtuvo en las parcelas libres de malezas (531.67), que es estadísticamente similar a Pretilacloro fb 1HW (505.42). El espaciamiento entre hileras de 10 cm mostró un número significativamente mayor de macollos efectivos

How to cite this article:
Devraj, S., Rajan, S., Sagar, B., & Santosh, M. (2023). Effect of row spacing and weed management practices on dry direct-seeded spring rice. *Peruvian Journal of Agronomy, 7*(2), 117-130. https://doi.org/10.21704/pja.v7i2.2013

por metro cuadrado (521.94). Se observó un mayor rendimiento de grano en las parcelas libres de malas hierbas (6397.87 kg.ha^{-1}), seguidas por Pretilacloro fb 1HW, que es estadísticamente similar a otras prácticas de manejo excepto el control de malas hierbas. Todas las prácticas de gestión resultaron eficaces para reducir parámetros de malas hierbas como la densidad, el peso seco y el *índice* de malezas en comparación con los controles. Se registró una relación positiva entre la altura de la planta a los 90 DAS y el rendimiento de grano, el peso de mil granos y el rendimiento de grano, y una relación negativa entre la densidad de malezas, la biomasa seca de malezas y el rendimiento de grano. Se recomienda aplicar Pretilaclor fb 1HW con una separación entre hileras de 10 cm para controlar eficazmente las malezas y aumentar el rendimiento del arroz de siembra directa seco.

Palabras clave: *Siembra directa en seco, Densidad de malezas, Índice de malezas, Rendimiento, Nepal*

1. Introduction dios de esspinoza

Rice (*Oryzae sativa*) is the third major cereal crop in the world and the first major crop in Nepal in terms of production (Agriculture Information and Communication Centre [AICC], 2019). It is a major source of calories for over half of the world's population (Kumar & Ladha, 2011). According to Ministry of Agriculture and Livestock Development (MoALD, 2022), it has contributed 20 % to agriculture gross domestic product (AGDP) and 7 % to gross domestic product (GDP). It is cultivated in Nepal at an altitude of 3 050 masl, from Jumla to the lowest point of 59 masl, Kachankawal (Paudel, 2011). Kanchanpur district has a latitude of 28° 50'13.9200" north and a longitude of 80°19'16.7232 east with an altitude of 176 m to 152 m from the masl. The total area cultivated under rice in Nepal was 1 458 915 ha, and the production was 5 550 878 t in the fiscal year 2077/78, with a productivity of 3.80 t.ha^{-1}. Similarly, the total area under rice in Kanchanpur district under main season and spring rice was 47 686 ha and 789 ha respectively, with a total production of 185 191 and 35.66 t, giving productivity of 3.88 t.ha^{-1} and 5.12 t.ha^{-1}, respectively (MoALD, 2022).

Rice is predominantly cultivated by transplanting in puddled soil with continuous flooding. Puddled transplantation causes the formation of hard pan at the sub-surface layer, thereby reducing soil permeability. Also, it is found that this method affects soil physical properties, affecting the growth and productivity of rice and succeeding wheat crops too (Gathala et al., 2011). Generally, transplanted rice suppressed the population of weeds through the formation of an anaerobic environment and reduced the percolation loss of water. But this method requires a lot of water and labor for land preparation, nursery establishment, and transplanting. Zhao et al (2007) reported that dry direct-seeded rice (DDSR) requires 25 % - 30 % less water as compared to puddled-transplanted rice. In contrast to transplanted rice, direct-seeded rice as an alternative is cost-effective and requires less labor. Labor used in direct fields is about 50 % lower than in puddled transplanted fields Kumar & Ladha (2011). The adoption of the direct-seeded method resulted in a 5.33 % increase in grain yield and a 7.51 % reduction in total production costs (Zhao et al., 2007; Mishra et al., 2017)the availability of appropriate land equipment, and irrigation-drainage systems. Using plot- and household-level data, we analyze the impacts of DSR adoption in two rice-growing states of India. We account for observed and unobserved heterogeneity using endogenous switching regression. We analyze the yield and costs effects of DSR adoption. Our study shows a small but significant effect of DSR adoption on yield and costs. We find increase in rice yields (by 3.74 %).

Weed management is a major constraint in direct-seeded rice (Ranjit & Suwanketnikom, 2005). The competition occurs between weeds and rice for sunlight, nutrients, space, and water, thereby reducing the potential yield. The order of weed dominance was 58 % broadleaf weeds, 20 % sedges, and 17 % types of grass at the DRR farm, which varies with location (Subbaiah, 2008). Furthermore, the random use of herbicides in the name of weed management has had brought several negative impacts on the environment. It causes harm to soil microorganisms, deteriorates the chemical properties of soil, and aids in the development of resistance in weeds against herbicides. Ayansina & Oso (2006) reported that herbicide treatments, even at the recommended dose, resulted in a reduced soil microbial count. Thus, row spacing can be an option for integrated weed management in combination with herbicides. Herbicides such as Pretilachlor and Pendimethalin were found effective for weed management in dry-direct seeded rice (Jabran & Chauhan, 2015). The morpho-physiological parameters such as plant height, tiller number pre-hill, total dry matter per hill, and yield of the plant are greatly affected by row spacing in rice (Roy et al., 2014). Thus, this research aims to evaluate the effect of weed management practices and row spacing on the performance of DDSR during the spring season.

2. Materials and methods

2.1 Description of research site

2.1.1 Location

The experiment was carried out in the farmer's field at Mahuliya, Kanchanpur, from 28th Magh, 2077 B.S. (10th February 2020) to 10th Asar, 2078 B.S. (24th July 2021). The site is situated 7.5 km south-east of Mahendranagar, the headquarter of Kanchanpur district. The experimental field was 176 meters above the mean sea level and located geographically at 28° 38'- 29° 28'N latitude and 80° 03'- 80° 33'E longitude.

2.1.2 Physio-chemical properties of the experimental soil

Soil samples were collected randomly from every four corners and a center experimental plot at 0 cm - 20 cm depth from the surface using a shovel to analyze the initial physio-chemical properties. From the analysis, the soil texture of the research plot was found to be sandy loam. The pH of the soil was neutral (6.84) in nature. The total nitrogen content of the soil was low (0.08 %), while available phosphorus (20.06 kg.ha^{-1}) and available potassium (121.2 kg.ha^{-1}) were low and medium, respectively. The organic matter content of the soil was low (1.68 %).

2.1.3 Weather conditions during the experiment

The experiment site lies in the sub-tropical region of Nepal. During the experimental period, the maximum temperature was 25 °C in June, while the minimum temperature was 14 °C in February. The relative humidity ranges from 29 % in April to 50 % in June as shown in Figure 1.

2.2 Sample and sampling techniques

First, the preliminary survey for major problems related to direct seeded rice was carried out near the areas of the superzone. The field research for

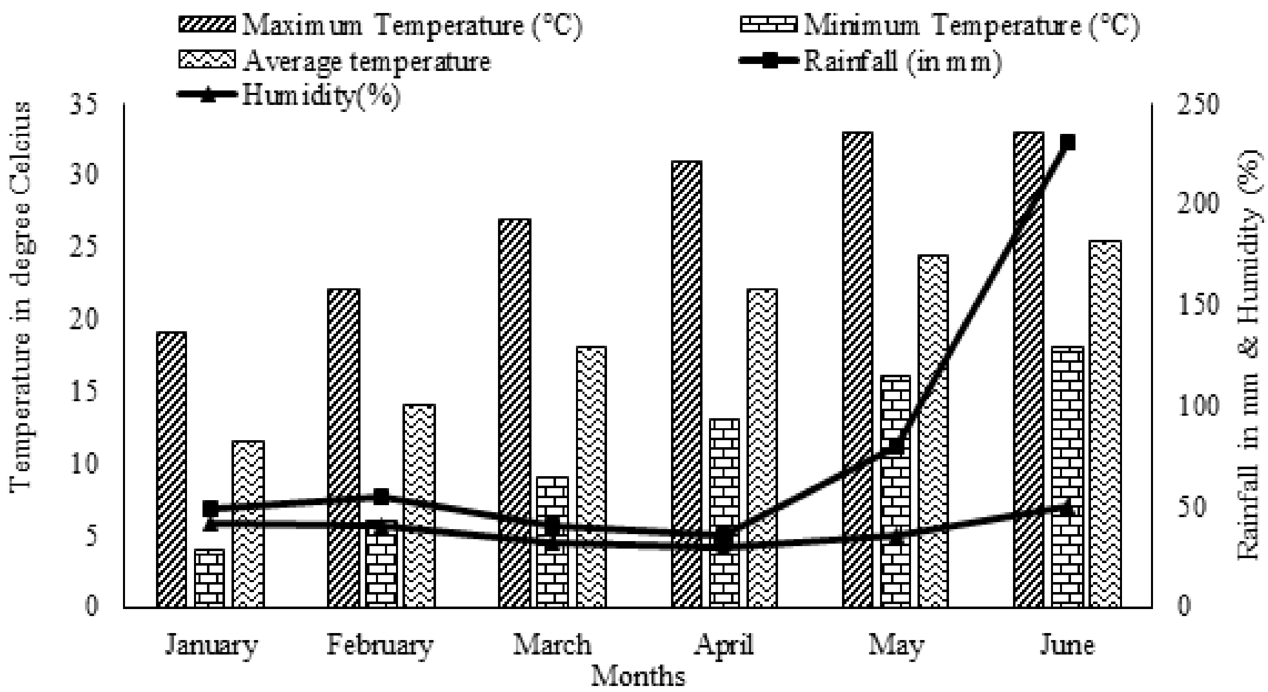

Figure 1.Weather conditions of the research site from January to June 2021

weed management under non-irrigated land by DSR (direct seeded rice) was conducted in the field of farmers who have been cultivating direct-seeded rice for a few years. The samples were collected from the replications made on the plots of rice fields. The samples from each plot were taken randomly excluding the border rows.

2.3 Experimental designs

The experimental design was two factorial RCBD with 12 treatments (Table 1) and 3 replications. Individual plot size was 2 $m^2 \times 2$ m^2 and the row spacing was 10 cm and 20 cm. The spacing between the blocks was 1m and the spacing between treatments was 0.5 m.

2.4 Details of Treatment and Layout

2.5 Crop management practices

Fertilizer application:

N, P, and K were applied at the recommended dose in the ratio of 120:40:40 $kg.ha^{-1}$, respectively. The full dose of potassium and phosphorus was applied as a basal. While one-third of the nitrogen was applied as basal and the remaining was applied in two split doses as top dressing at tillering and panicle initiation stages (Dangol et al., 2020).

Seed rate and sowing:

The sowing of seeds was done on 24th February 2021. They were sown directly in rows by maintaining the spacing of 10 cm and 20 cm. The seed rate was 24 g/plot. The seeds were first treated with salt at a rate of 200-300 g/L of water (Dangol et al., 2020). The seeds were sown manually.

Treatment Application and Inter-cultural Operations:

One Hand weeding was practiced at 30 DAS (days after sowing), and in weed-free plots, hand weeding was practiced at intervals of 7 days up to the panicle initiation stage. Gap filling was done at 15 DAS. Imidacloprid was sprayed at 20 DAS to control aphids and plant hopper (Table 2).

2.6 Measurement

2.6.1 Data related to Weeds

Weed density:

The number of weeds that emerged was counted in the area between the 18th and 19th row and 8th and 9th rows of rice in 10cm and 20cm row spacing respectively, i.e., from 0.1 m^2 (50 cm × 20 cm) at 30, 60, and 90 DAS.

Weed dry weight:

Weed samples were taken from the inter-row space between the 18th and 19th and 8th and 9th intervals in row spacing of 10 cm and 20 cm, respectively, at 30 DAS, 60 DAS, and 90 DAS for each treatment. At the time of sampling, weeds were taken from an area of 0.1m^2 (50cm × 20cm) and values were converted to per square meter. Dry matter deposition was determined by oven-drying weed samples at 70 °C for 48 hours.

Table 1. Treatment details

Treatment number	Treatment combination	Symbols
T_1	10cm + Pendimethalin *fb* 1- HW	S_1W_1
T_2	10cm + Pretilachlor *fb* 1-HW	S_1W_2
T_3	10cm + Pendimethalin *fb* 2,4-D Ethyl ester	S_1W_3
T_4	10cm + Pretilachlor *fb* 2,4-D Ethyl ester	S_1W_4
T_5	10cm + weed-free	S_1W_5
T_6	10cm + weed check	S_1W_6
T_7	20cm + Pendimethalin *fb* 1- HW	S_2W_1
T_8	20cm + Pretilachlor *fb* 1-HW	S_2W_2
T_9	20cm + Pendimethalin *fb* 2,4-D Ethyl ester	S_2W_3
T_{10}	20cm + Pretilachlor *fb* 2,4-D Ethyl ester	S_2W_4
T_{11}	20cm + weed-free	S_2W_5
T_{12}	20cm + weed check	S_2W_6

Table 2. Weed management practices

Weed management	Dose a.i. mL/L	Days after sowing
Pendimethalin	4 mL/L water	3
Pretilachlor	2 mL/L water	3
2,4-D Ethyl ester	1 mL/L water	25
Hand weeding	-	30

Weed Index (WI):

It refers to the reduction in yield due to the presence of weeds in comparison to the weed-free plot. It was calculated using the following formula given by Gill & Vijaya Kumar (1969).

$$WI = [(X-Y)/X] * 100$$

Where,

X= Yield from the weed-free plot

Y= Yield from the treated plot

2.6.2 Biometrical observations

Plant height (cm):

Plant height was measured from randomly selected plants excluding border rows at an interval of 15 days from 30 DAS up to 90 DAS. For height, the vertical distance was measured from the ground level of the plant to the longest leaf of the main tiller with the help of scale and was averaged.

The number of tillers/m^2:

It was calculated by using a non-destructive sampling technique at 15-day intervals from 30 days after sowing up to 90 days after sowing and the average was computed.

2.6.3 Yield and yield attributing parameters of Rice

The number of effective tillers/m^2:

An effective tiller refers to that tiller which yields panicle on it. It was computed just before the harvesting stage.

Length of panicle, grain/panicle, and sterility percentage

They were calculated from randomly selected 20 panicles excluding border rows just before harvesting. The sterility percentage was computed by determining the number of filled and unfilled florets from the selected panicles. The sterility percentage was computed by using the following formula,

Sterility (%)=[number of sterile florets/total number of florets] × 100

Thousand-grain weight:

It was computed from the randomly selected grains, and weighed by using an electronic balance.

Grain and straw yield (kg ha^{-1}):

Moisture content in grains was measured by using Wile 65 moisture meter. Grain yield at 14 % moisture was calculated using the formula suggested by Paudel (1995). For straw yield, the grain yield was deducted from the total biomass.

where,

MC = moisture content (%) in grains

Grain yield (kg ha^{-1}) at 0 % moisture = Grain yield (kg.ha^{-1}) at 14% moisture×0.86

Harvest index:

It is the ratio of the economic yield to the total yield of biomass. It was computed by using the given formula,

Harvest index (HI) = (Grain yield)/(Total biomass yield)

Grain yield (kg.ha^{-1}) at 14 % moisture = ((100-MC)×plot yield (kg)×10000m^2)/((100-14)×netplot area (in square meter))

2.7 Data analysis

The data entry was done in MS Excel and analyzed in R Studio of version 4.1.2. The mean comparison was done through Duncan`s Multiple Range Test (DMRT) at a 5 % level of significance and F-test at 1 % level of significance.

3. Results and Discussion

3.1 Influence of weed management practices and row spacing on crop parameters

3.1.1 Biometrical data

3.1.1.1 Plant height

Plant height in dry DSR was significantly influenced by weed management practices, but on row spacings of 10 cm and 20 cm, the plant height was found to be statistically similar during all days of observation from 30 DAS to 90 DAS (Table 3). Row spacing had no significant influence on plant height (Payman & Singh, 2008). At all dates of observations, the tallest plant height was recorded in weed-free plots, whereas the shortest plant height was observed on weedy check plots. At 30 DAS, the plant height was observed to be significantly highest in weed-free plots (21.02 cm). At 45 DAS, the tallest plant height was observed in weed-free plots (31.70 cm). Plant height in pendimethalin *fb* 1HW-treated plots at 45 DAS was found to be statistically similar to pretilachlor *fb* 1HW-treated plots. At 60 DAS, plant height in weed-free plots (41.01 cm) was found to be statistically higher, which was statistically similar to pendimethalin *fb* 2,4-D EE (38.94 cm)-treated plots. At 75 DAS, plant height was observed to be statistically higher in weed-free plots, followed by pendimethalin *fb* 1HW, pretilachlor *fb* 1HW, and pendimethalin and pretilachlor *fb* 2,4-d EE. At 90 DAS, the plant height of weed-free (69.93 cm) and pendimethalin *fb* 1HW (68.42 cm) were statistically similar.

3.1.1.2 Number of tillers/m^2

At 30DAS, 45DAS, and 60 DAS, the highest number of tillers per square meter was observed on the weed-free plot, followed by the pretilachlor *fb* 1HW-treated plot and pendimethalin *fb* 1HW-

Table 3. Influence of weed management practices and row spacing on plant height (cm) of dry DSR at different dates of observation at Kanchanpur, Nepal, 2021

Treatments	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Weed management					
Pendimethalin *fb* 1HW	19.18^{b}	29.48^{b}	38.94^{ab}	52.35^{b}	68.42^{ab}
Pretilachlor *fb* 1HW	18.98^{b}	28.68^{bc}	38.38^{bc}	49.96^{c}	65.91^{bc}
Pendimethalin *fb* 2,4-d EE	19.61^{b}	27.12^{cd}	35.54^{de}	47.03^{d}	64.81^{c}
Pretilachlor+2,4-d EE	18.46^{b}	26.06^{d}	36.11^{cd}	46.79^{d}	63.64^{c}
Weedy free	21.02^{a}	31.70^{a}	41.01^{a}	54.87^{a}	69.93^{a}
Weed check	17.03^{c}	22.34^{e}	33.50^{e}	42.17^{e}	59.18^{d}
SEm (±)	0.15	0.27	0.33	0.27	0.37
LSD (=0.05)	1.08	1.92	2.40	1.97	2.65
F-test	***	***	***	***	***
Row Spacing					
10cm	18.83	27.17	37.40	49.11	65.76
20cm	19.27	27.95	37.10	48.61	64.87
SEm (±)	0.05	0.09	0.11	0.09	0.12
LSD (=0.05)	0.62	1.11	1.38	1.14	1.53
F-test	ns	ns	ns	ns	ns
CV (%)	4.74	5.83	5.37	3.37	3.39
Grand mean	19.05	27.56	37.25	48.86	65.31

Note: *fb*, followed by; DAS, days after sowing; SEm, standard error of the mean; LSD, least significance difference, CV, coefficient of variation. Treatment means followed by the same letter(s) are non-significance differences on Duncan multiple range test (p > 0.05).

treated plot. At 30 DAS, the number of tillers per square meter on pendimethalin *fb* 1HW was found to be statistically similar with pendimethalin *fb* 2,4-D EE and Pretilachlor *fb* 2,4-D EE-treated plots. At 45 DAS, the numbers of tillers per square meter in pendimethalin *fb* 2,4-D EE were found to be at par to pretilachlor *fb* 2,4-D EE and weedy check. At 60 DAS and 75 DAS, pendimethalin *fb* 1HW and pretilachlor *fb* 1HW treated plots were found to be statistically similar to the weedy check plot. At 90 DAS, numbers of tillers per square meter in weed-free plots and pretilachlor *fb* 1HW were found statistically superior, followed by pendimethalin *fb* 1HW and pretilachlor *fb* 2,4-d EE respectively. At 90 DAS, the number of tillers per square meter in the weedy check plot is the lowest (380.00). At all dates of observation, the highest number of tillers was statistically observed in 10cm row spacing (327, 739, 896, 994, 544) as compared to 20 cm row spacing (203, 465, 697, 840), respectively (Table 4). The number of tillers increases with increasing row spacing, which is similar to the finding of Roy et al (2014). But, in the case of unit area basis, the number of tillers in narrow row spacing was found to be higher at a row spacing of 10 cm.

3.1.2 Yield attributing parameters

3.1.2.1 Effective tillers/m^2

The effective tillers per square meter of dry DSR were significantly influenced by weed management practices and row spacing. Weed-free plots had the highest number of effective tillers per square meter numerically (531.67), which was statistically superior to other treatments but statistically at par with pretilachlor *fb* 1HW. The number of effective tillers per meter square was found to be significantly lower in weedy check plots numerically (332.50) because of higher weed density and dry weight, along with a lower number of tillers per meter square. The higher number of effective tillers in weed-free and pretilachlor *fb* 1HW-treated plots might be due to the higher number of tillers. The effective tillers per square meter were statistically higher at a row spacing of 10cm as compared with a row spacing of 20 cm. In a wider row spacing of 20 cm, plants get more nutrients, moisture, and light, as a result of which the number of effective tillers becomes higher, but per unit area, it decreases due to the lesser number of rows.

Table 4. Influence of weed management practices and row spacing on the number of tillers per square meter of dry DSR at different dates of observation at Kanchanpur, Nepal, 2021

Treatments	Number of tillers per square meter				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Weed management					
Pendimethalin *fb* 1HW	261.67[b]	650.00[c]	782.50[c]	961.67[bc]	491.61[b]
Pretilachlor *fb* 1HW	343.33[a]	766.67[b]	985.00[b]	1069.17[ab]	597.50[a]
Pendimethalin *fb* 2,4-d EE	200.83[bc]	437.50[de]	651.67[cd]	800.83[cd]	443.33[bc]
Pretilachlor *fb* 2,4-d EE	214.17[bc]	473.33[d]	671.67[cd]	746.67[cd]	485.83[b]
Weedy free	384.17[a]	944.17[a]	1170.83[a]	1286.67[a]	680.33[a]
Weed check	183.33[c]	338.33[e]	515.83[d]	638.33[d]	380.00[c]
SEm (±)	9.95	14.68	22.53	34.59	12.57
LSD (=0.05)	71.51	105.46	161.87	248.52	90.29
F-test	***	***	***	***	***
Row spacing					
10cm	326.67[a]	738.89[a]	895.93[a]	994.17[a]	544.28[a]
20cm	202..50[b]	464.44[b]	696.67[b]	840.28[b]	481.95[b]
SEm (±)	3.32	4.90	7.51	11.53	4.19
LSD (=0.05)	41.29	60.88	93.46	143.48	52.13
F-test	***	***	***	*	*
CV (%)	22.57	14.63	16.98	22.63	14.70
Grand mean	264.58	601.67	796.25	917.22	513.11

Note: *fb*, followed by; DAS, days after sowing; SEm, standard error of the mean; LSD, least significance difference, CV, coefficient of variation. Treatment mean followed by the same letter(s) are non-significance differences on Duncan multiple range test (p > 0.05).

3.1.2.2 Panicle length, sterility percentage, and thousand-grain weight

The weed management practices had a significant influence on panicle length but not on the sterility percentage and thousand-grain weight. The pretilachlor *fb* 2,4-d EE-treated plots had the longest panicle (24.50 cm) among all the treatments and were statistically similar to pendimethalin *fb* 2,4-d EE (Table 5). The panicle length was observed to be statistically shorter in weedy check plots, which might be due to nutrient drain resulting from higher crop-weed competition for limited nutrients. The row spacing had no significant influence on sterility percentage, panicle length, and thousand-grain weight. Probably, the parameter thousand grain weight, is not affected by row spacing because it is a varietal character and controlled by the hull (Yadanar et al., 2018).

3.1.3 Yield

3.1.3.1 Grain Yield, straw yield, and harvest index

The different weed management practices were found to have a significant influence on grain yield and straw yield, but not on harvest index. The highest grain yield was recorded on the weed-free plots (6394.87 kg ha^{-1}). Pretilachlor *fb* 1HW, pendimethalin *fb* 1HW, and pretilachlor *fb* 2,4-D EE-treated plots produced significantly higher grain yield than the weedy check. Pendimethalin *fb* 2,4-D EE plots were produced statistically at par grain yield to weedy check plot (Table 6). The statistically lower position was obtained by Weedy check plots (2119.19 kg ha^{-1}), which might be due to inferior performance in terms of some yield-attributing parameters. Increased grain yield as a result of an effective weedy check through herbicides was reported by Ishaya et al (2007). Akbar et al (2011) and Choudhary & Dixit (2018) reported that the order of herbicides in improving grain yield was pretilachlor, followed by pendimethalin. The grain yield of direct-seeded spring rice was maximum on plots treated with pretilachlor at a rate of 900 g ai/ha (Chauhan et al., 2014). The highest dry straw yield was 16943.14 kg ha^{-1} recorded with weed-free plots, which were found to be significantly similar to pretilachlor *fb* 2,4-D EE-treated plots. Among the six weed treatments, pretilachlor *fb* 1HW-treated plots occupied statistically similar positions to other weed-treated plots. The row spacing had no significant impact on grain yield, straw yield, and harvest index. Chauhan

Table 5. Influence of weed management practices and row spacing on yield attributes of dry DSR at different dates of observation at Kanchanpur, Nepal, 2021

Treatments	Effective tiller m^{-2}	Panicle length (cm)	Sterility (%)	Thousand-grain weight (g)
Weed management				
Pendimethalin *fb* 1HW	442.92[bc]	21.97[b]	41.24	22..13
Pretilachlor *fb* 1HW	505.42[ab]	21.92[b]	42.60	22.18
Pendimethalin *fb* 2,4-d EE	387.08[cd]	23.98[a]	43.80	21.03
Pretilachlor *fb* 2,4-d EE	390.42[cd]	24.50[a]	44.74	21.53
Weedy free	531.67[a]	21.77[b]	39.59	22.11
Weed check	332.50[d]	20.97[b]	37.13	21.19
SEm (±)	10.81	0.15	0.81	0.13
LSD (=0.05)	77.67	1.07	5.83	0.90
F-test	***	***	ns	ns
Row spacing				
10 cm	521.94[a]	22.40	42.42	21.81
20 cm	341.39[b]	22.64	40.66	21.59
SEm (±)	3.60	0.05	0.27	0.04
LSD (=0.05)	44.84	0.62	3.37	0.55
F-test	***	Ns	Ns	Ns
CV (%)	15.03	3.99	11.72	3.67
Grand mean	431.66	22.52	41.54	21.69

Note: *fb*, followed by; DAS, days after sowing; SEm, standard error of the mean; LSD, least significance difference, CV, coefficient of variation. Treatment mean followed by the same letter(s) are non-significance differences on Duncan multiple range test (p > 0.05).

& Johnson (2011) also reported no significant impact of row spacing between 15 cm and 10-20-10 cm rows on weed growth and yield of aerobic rice.

3.2 Influence of weed management practices and row spacing on weed parameters

3.2.1 Weed density

The weed density was significantly influenced by weed management practices except at 90 DAS and also had no significant influence by row spacing except at 60 DAS (Table 7). The integration of narrow row spacing with a high seed rate helps in effectively controlling the weed population (Matloob et al., 2015). At 30 DAS, the significantly highest weed density was observed in the weedy check, and the lowest was observed in pendimethalin *fb* 1HW. Mishra & Singh (2008) also reported significant control of *Echinochloa colona* on the application of pendimethalin 1 kg/ha *fb* 1 HW in DDSR. At 30 DAS, the pendimethalin *fb* 1HW was statistically similar to the remaining treated plot except the weed-free plot. At 60 DAS, the significantly lowest weed density was obtained in the weed-free plots, which was at par with pendimethalin *fb* 2,4-d EE. The effect of pendimethalin *fb* 2,4-d EE and pretilachlor *fb* 2,4-d EE on weed density was observed to be similar at 60 DAS. Chauhan et al (2014) also reported the lowest weed density at a high dose of pretilachlor in direct-seeded spring rice.

3.2.2 Weed dry weight (g/m^2)

The dry weight of weed biomass was significantly influenced by weed management practices but not significantly influenced by row spacing (F-test, p<0.01). At 30 DAS, the weed-free plot is statistically similar to the remaining treated plot. At 60 DAS, weed biomass in pendimethalin *fb* 2,4-D EE, pendimethalin 1HW, pretilachlor *fb* 2,4-D EE, and pretilachlor 1HW is statistically similar to each other. Chauhan et al (2014) found significantly low weed biomass with an increase in the dose of pretilachlor. The application of pretilachlor at a rate of 0.5 kg/ha resulted in decreased weed biomass and increased grain yield in direct-seeded rice (Phukan et al., 2021). At 90 DAS weedy dry matter, the weedy check plot was found to be similar to the pendimethalin 2,4-D EE and pretilachlor *fb* 2,4-D EE-treated plots (Table 8).

Table 6. Influence of weed management practices and row spacing on yield per hectare of dry DSR at different dates of observation at Kanchanpur, Nepal, 2021

Treatments	Grain yield (kg ha^{-1})	Straw weight (kg ha^{-1})	Harvest Index
Weed management			
Pendimethalin *fb* 1HW	4752.06^{b}	10563.10^{b}	0.25
Pretilachlor *fb* 1HW	4776.04^{b}	10843.92^{b}	0.28
Pendimethalin *fb* 2,4-D EE	3438.85^{bc}	8803.11^{b}	0.25
Pretilachlor *fb* 2,4-D EE	4530.23^{b}	12074.54^{ab}	0.23
Weedy free	6394.87^{a}	16943.14^{a}	0.24
Weed check	2119.91^{c}	9359.79^{b}	0.19
SEm (±)	183.82	715.52	0.011
LSD (=0.05)	1320.58	5140.37	0.08
F-test	***	*	Ns
Row spacing			
10 cm	4145.44	11250.97	0.24
20 cm	4525.21	11611.56	0.24
SEm (±)	61.27	238.51	0.003
LSD (=0.05)	762.44	2967.80	0.04
F-test	Ns	Ns	Ns
CV (%)	25. 44	37.56	27.7
Grand mean	4335.32	11431.27	0.25

Note: *fb*, followed by; DAS, days after sowing; SEm, standard error of the mean; LSD, least significance difference, CV, coefficient of variation. Treatment means followed by the same letter(s) are non-significance differences on Duncan multiple range test (p > 0.05).

Table 7. Influence of weed management practices and row spacing on Total weed density at DSR at different dates of observation at Kanchanpur, Nepal, 2021

Treatments	Weed density		
	30DAS	60DAS	90DAS
Weed management practices			
Pendimethalin *fb* 1HW	7.16^{c}(55.00)	27.24^{b}(800.00)	21.16(541.67)
Pretilachlor *fb* 1HW	9.22^{bc} (90.00)	22.05^{bc} (515.00)	17.12(305.00)
Pendimethalin *fb* 2,4-d EE	10.06^{bc} (118.33)	12.67^{de} (195.00)	14.87(240.00)
Pretilachlor *fb* 2,4-d EE	9.66^{bc} (105.00)	19.32^{cd} (396.67)	16.80(285.00)
Weedy free	12.26^{b} (153.33)	9.43^{e} (95.00)	10.54(115.00)
Weed check	33.47^{a} (1140.00)	39.93^{a} (1851.67)	17.25(306.67)
SEm (±)	0.61	0.98	0.93
LSD (=0.05)	4.35	7.05	6.67
F-test	***	***	Ns
Row spacing			
10 cm	14.42(298.89)	24.37^{a}(811.11)	17.98(372.22)
20 cm	12.86(172.22)	19.17^{b}(473.33)	14.60(225.56)
SEm (±)	0.20	0.32	0.31
LSD (=0.05)	2.51	4.07	3.85
F-test	Ns	*	Ns
CV%	12.86	27.06	34.20
Grand mean	13.64	21.77	16.47

Note: *fb*, followed by; DAS, days after sowing; SEm, standard error of the mean; LSD, least significance difference, CV, coefficient of variation. Treatment mean followed by the same letter(s) are non-significance differences on Duncan multiple range test (p > 0.05). The figures in the parenthesis represent the original value and outside the parenthesis the square root transformation value (√(x+0.5)

Table 8. Influence of weed management practices and row spacing on weed dry weight at DSR at different dates of observation at Kanchanpur, Nepal, 2021

Treatments	Dry weight (g.m^{-2}) of weed biomass		
	30DAS	60DAS	90DAS
Weed management practices			
Pendimethalin *fb* 1HW	0.87^{b}(0.27)	15.38^{b}(240.49)	18.44^{c} (344.2)
Pretilachlor *fb* 1HW	0.95^{b}(0.42)	13.69^{b}(203.15)	19.37^{bc} (385.3)
Pendimethalin *fb* 2,4-d EE	1.71^{b}(3.95)	15.55^{b}(255.23)	22.89^{ab} (537.95)
Pretilachlor *fb* 2,4-d EE	1.57^{b}(3.09)	14.40^{b}(209.66)	21.18^{abc} (459.97)
Weedy free	0.97^{b}(0.45)	6.78^{c}(45.46)	7.61^{d}(58.77)
Weed check	6.81^{a}(47.55)	29.14^{a}(857.41)	24.55^{a}(606.10)
SEm (±)	0.15	0.45	0.47
LSD (=0.05)	1.04	3.20	3.41
F-test	***	***	***
CV (%)	40.61	16.90	14.97
Row spacing			
10 cm	2.29(9.65)	15.72(309.24)	19.86(433.93)
20 cm	2.00(8.93)	15.93(294.57)	18.15(363.50)
SEm (±)	0.05	0.15	0.16
LSD (=0.05)	0.60	1.85	1.96
F-test	ns	ns	ns
CV (%)	40.61	16.90	14.97
Grand mean	2.15	15.82	19.01

Note: *fb*, followed by; DAS, days after sowing; SEm, standard error of the mean; LSD, least significance difference, CV, coefficient of variation. Treatment mean followed by the same letter(s) are non-significance differences on Duncan multiple range test (p > 0.05); the numbers in parenthesis represent the original value and outside the parenthesis the square root transformation value (√(x+0.5)

3.2.3 Weed index

The weed index of DDSR as influenced by different weed management practices is presented in Figure 2. The grand mean weed index for the experiment was 31.57 % and ranges from 23.67 % to 67.85 %. The weed index was significantly influenced by various weed management practices. Among the weed management practices, there was a 66.78 % yield reduction in the weedy check plot, which was significantly higher and statistically similar to pendimethalin *fb* 2,4-D EE. The weed index of the plot treated with pretilachlor *fb* 1HW (23.67 %), pendimethalin *fb* 1HW, and pretilachlor *fb* 2,4-D EE was significantly lowest and at par with pendimethalin *fb* 2,4-D.

3.3 Regression analysis of various parameters

3.3.1 Plant height at 90 DAS and grain yield

There is a linear relationship between Plant height at 90 DAS and grain yield. The Plant height at 90 DAS had only a 67.6 % contribution to the total grain yield and the remaining contribution was due to other factors (Figure 3).

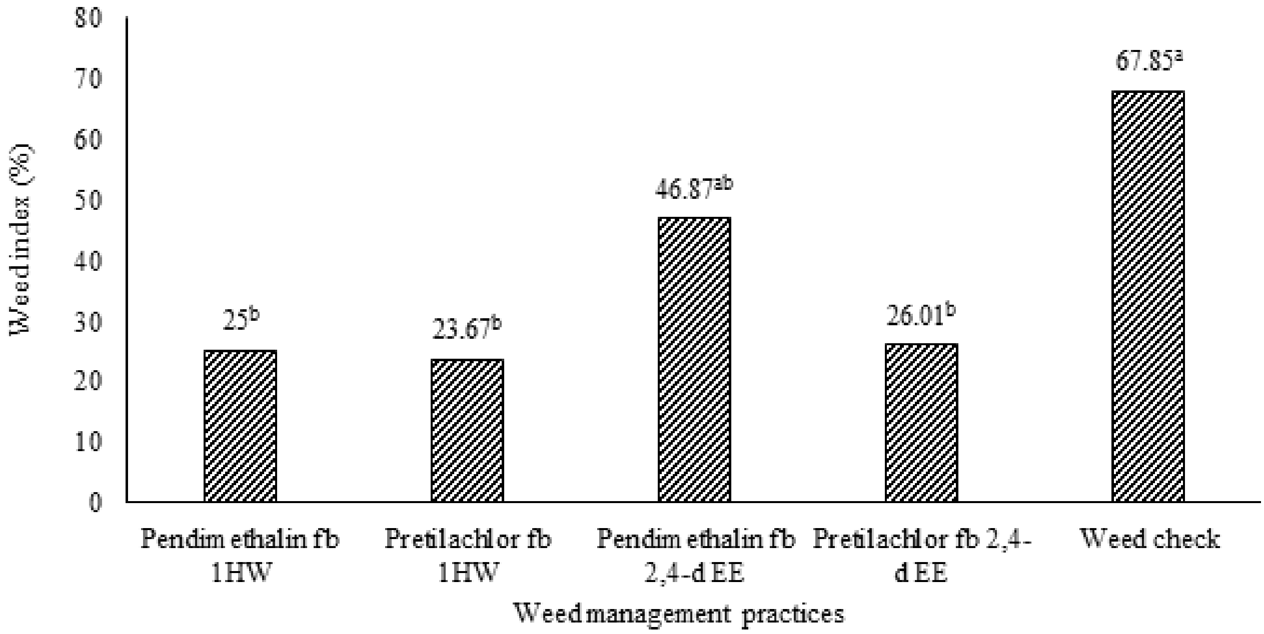

Figure 2: Weed index (%) as influenced by different weed management practices

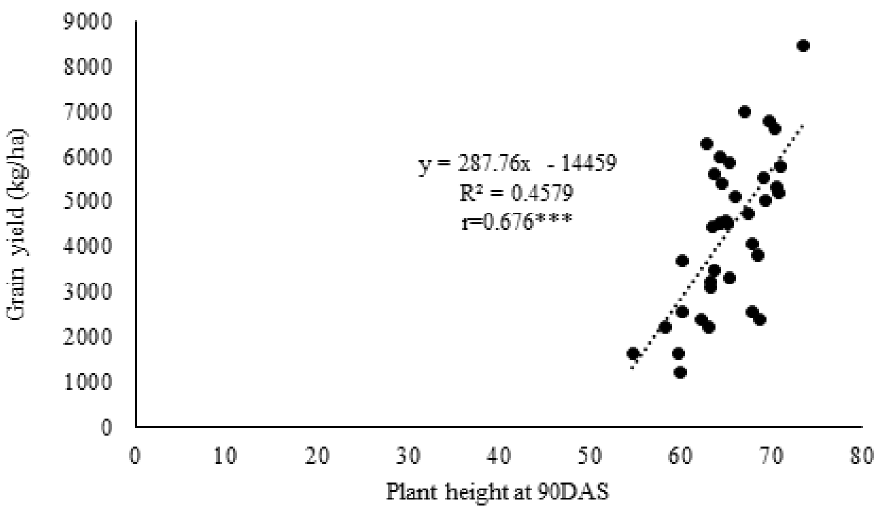

Figure 3: Relation between plant height at 90 DAS and grain yield as influenced by weed management practices at Kanchanpur, Nepal, 2021

3.3.3 Weed Density and grain yield

There is a linear relationship between weed density at 30 DAS and 60 DAS with grain yield. The weed density at 30 DAS had only a 55.1 % reduction to the total grain yield and the remaining contribution was due to other factors. The weed density at 60 DAS had only a 50.6 % reduction to the total grain yield and the remaining contribution was due to other factors (Figure 4).

Conclusion

The different weed management practices had a significant influence on the growth and yield parameters of DDSR and weeds. After weed-free plots, pendimethalin *fb* 1HW showed significantly more plant height, which was at par with pretilachlor *fb* 1HW. The yield attributing parameter, effective tillers/m^2, was significantly highest in weed-free plots, which were at par with pretilachlor *fb* 1HW. The panicle length was highest in plots treated with pretilachlor *fb* 2,4-d EE, which was similar to pendimethalin *fb* 2,4-d EE. The weed-free plots showed maximum grain yield, followed by pretilachlor *fb* 1HW, which was similar to all the other management practices except weed check. However, weed check and pendimethalin *fb* 2,4-D EE showed similar effects on grain yield. After weed-free plots, all the weed management practices except weedy check were at par in controlling weed density, weed dry weight, and weed index. The weed index observed in the weedy check and pendimethalin *fb* 2,4-d EE were statistically similar. There was a reduction in yield of 67.85 % due to the presence of weeds as compared to weed-free. Among row spacing, tiller and effective tiller per square meter were found to be higher in 10 cm row spacing as compared with 20 cm row spacing. During the overall date of observation, there was no significant influence of row spacing on weed density and weed dry weight except weed density at 60 DAS. The treatment with pretilachlor *fb* 1HW and 10 cm row spacing is recommended for improving the growth, yield, and yield attributing parameters of dry-direct seeded rice and also for effective control of the weed population.

Author contributions

DSJ: Conceptualization, experimental design, data collection and analysis, editing; RS: Experimental design, data collection, data analysis, and editing; SB: Experimental design, data analysis, editing, and revision; SM: supervision, editing, and data analysis.

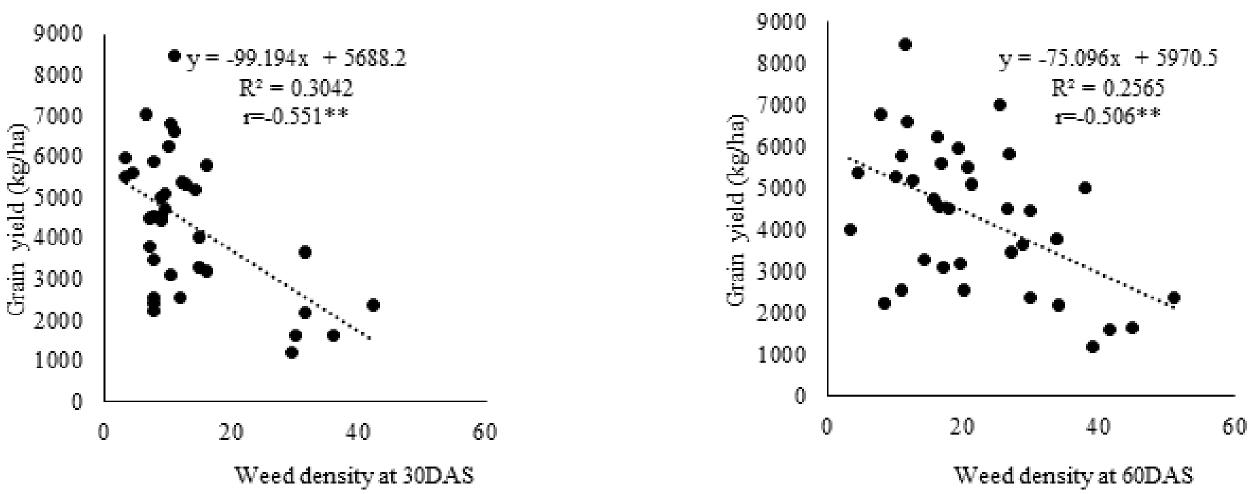

Figure 4: Relation between weed density at 30 DAS and 60 DAS and grain yield as influenced by weed management practices at Kanchanpur, Nepal, 2021

Declaration of interest statement

All the authors declare that there is no conflict of interest.

Funding statement

This research was funded by Prime Minister Agriculture Modernization Project (PMAMP).

ID ORCID and e-mails

Devraj Sharma Jaishi razzdev372@gmail.com
https://orcid.org/0009-0002-5349-7869

Rajan Sah agriculture.rajan@gmail.com
https://orcid.org/ 0009-0002-4989-4589

Sagar Bhandari: sagarbhandari88484@gmail.com
https://orcid.org/0000-0002-4745-3184

Santosh Marahatta smarahatta@afu.edu.np
https://orcid.org/0000-0002-3755-8812

References

Agriculture Information and Communication Centre (2019). Krishi diary. Lalitpur, Nepal: Ministry of agriculture, land reforms and cooperative.

Akbar, N., Jabran, K., & Ali, M. A. (2011). Weed management improves yield and quality of direct seeded rice. *Australian Journal of Crop Science, 5*(6), 688–694.

Ayansina, A. D. V., & Oso, B. A. (2006). Effect of two commonly used herbicides on soil microflora at two different concentrations. *African Journal of Biotechnology, 5*(2), 129–132.

Chauhan, B. S., & Johnson, D. E. (2011). Row spacing and weed control timing affect yield of aerobic rice. *Field Crops Research*, *121*(2), 226–231. https://doi.org/10.1016/j.fcr.2010.12.008

Chauhan, B. S., Ngoc, S. T. T., Duong, D., & Le Ngoc, P. (2014). Effect of pretilachlor on weedy rice and other weeds in wet-seeded rice cultivation in South Vietnam. *Plant Production Science*, *17*(4), 315–320. https://doi.org/10.1626/pps.17.315

Choudhary, V., & Dixit, A. (2018). Herbicide weed management effect on weed dynamics, crop growth and yield in direct-seeded rice. *Indian Journal of Weed Science*, 6–12. https://doi.org/10.5958/0974-8164.2018.00002.3

Dangol, R., Pandey, S. R., Shrestha, B., Thapa Magar, D. B., & Bhattarai, N. (2020). Effects of different weed management practices on growth and yield of direct-seeded spring rice in Jhapa, Nepal. *Cogent Food & Agriculture*, *6*(1), 1825040. https://doi.org/10.1080/23311932.2020.1825040

Gathala, M. K., Ladha, J. K., Saharawat, Y. S., Kumar, V., Kumar, V., & Sharma, P. K. (2011). Effect of Tillage and Crop Establishment Methods on Physical Properties of a Medium-Textured Soil under a Seven-Year Rice−Wheat Rotation. *Soil Science Society of America Journal, 75*(5), 1851–1862. https://doi.org/10.2136/sssaj2010.0362

Gill, G. S. & Vijaya Kumar, K. (1969). Weed Index—A New Method of Reporting Weed Control Trials. *Indian Journal of Agronomy*, 14, 96−98.

Ishaya, D., Dadari, S., & Shebayan, J. (2007). Evaluation of herbicides for weed control in three varieties of upland rice (*Oryza sativa* L.) in the Nigerian Savannah. *Crop Protection, 26*(10), 1490–1495. https://doi.org/10.1016/j.cropro.2006.12.015

Jabran, K., & Chauhan, B. S. (2015). Weed management in aerobic rice systems. Crop Protection, 78, 151–163. https://doi.org/10.1016/j.cropro.2015.09.005

Kumar, V., & Ladha, J. K. (2011). Direct Seeding of Rice. Recent Developments and Future Research Needs. *Advances in Agronomy, 111*, 297–413. https://doi.org/10.1016/B978-0-12-387689-8.00001-1

Matloob, A., Khaliq, A., & Chauhan, B. S. (2015). Weeds of direct-seeded rice in Asia: problems and opportunities. *Advances* *in Agronomy, 130*, 291–336. https://doi.org/10.1016/bs.agron.2014.10.003

Mishra, J. S., Rao, A. N., Singh, V. P., & Kumar, R. (2017). Weed management in major field crops. *Advances in Weed Management* (pp. 1-21). Indian Society of Agronomy

Mishra, J. S., & Singh, V. P. (2008). Integrated weed management in dry-seeded irrigated rice (*Oryza sativa*). *Indian Journal of Agronomy*, *53*(4), 299–305.

Ministry of Agriculture and Livestock Development (2022). Statistical Information in Nepalese Agriculture. https://moald.gov.np/wp-content/uploads/2022/07/STATISTICAL-INFORMATION-ON-NEPALESE-AGRICULTURE-2077-78.pdf

Paudel, M. N. (1995). *Nutrient management for Sulphan buri-900 rice variety in acid sulfate soil with green leaf manure* [Master's thesis, Asian Institute of Technology].

Paudel, M. (2011). Rice (*Oryza sativa* L) cultivation in the highest elevation of the world. *Agronomy Journal of Nepal, 2*, 31–41. https://doi.org/10.3126/ajn.v2i0.7519

Payman, G., & Singh, S. (2008). Effect of Seed Rate, Spacing and Herbicide Use on Weed Management in Direct Seeded Upland Rice (*Oryza sativa* L.). *Indian Journal of weed Science, 40*(1 & 2), 11–15. https://isws.org.in/IJWSn/File/2008_40_Issue-1&2_11-15.pdf

Phukan, J., Kalita, S., & Bora, P. (2021). Weed management in direct seeded rice: A review. *Journal of Pharmacognosy and Phytochemistry*, *10*(2), 742–748.

Ranjit, J. D., & Suwanketnikom, R. (2005). Response of weeds and yield of dry direct seeded rice to tillage and weed management. Agriculture and Natural Resources, 39(2), 165–173.

Roy, T. S., Pulok, A. I., Rahman, M., & Hussain, A. (2014). Effect of varieties and row spacing on the growth and yield of AUS rice. *Bangladesh Research Publications Journal, 10*(2), 138–144.

Subbaiah, S. V. (2008). Studies on weed and water management in direct- seeded rice. In Y. Singh, V. P. Singh, B. Chauhan, A. Orr, A. M. Mortimer, D. E. Johnson, & B. Hardy (eds.), *Direct Seeding of Rice and Weed Management in the Irrigated Rice-wheat Cropping System of the Indo-Gangetic Plains* (pp. 177–189). Int. Rice Res. Inst. http://books.irri.org/9789712202360_content.pdf

Yadanar, S. M., Mar, S. S., Than, A. A., & Ngwe, K. (2018). Effect of Nitrogen and Potassium on Yield and Yield components of Rice. *Proceedings of the eleventh Agricultural Research Conference, Yezin Agricultural University, Myanmar*.

Zhao, C., Jiang, H., Ren, C., Yin, Y., & Li, Y. (2007). Studies on key techniques of sowing rice directly on dry land for high yield and high efficiency. *J. Jilin Agr. Sci., 32*, Pp. 9–11.