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# Weed Control Efficiencies, Grain Yield and Economics as Affected by Seedbed Preparation and Weed Management Practices in Central Terai, Nepal

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## ABSTRACT

Grain yield under dry direct seeded rice (DDSR) is primarily limited due to weeds. Therefore, a field experiment was conducted at Rampur, Chitwan during the monsoon season, of 2014. The treatments consisted of two methods of seedbed preparation in the main plot and six weed management methods in the sub-plot arranged in split plot design with four replications. Results revealed that the grain yield of dry-direct seeded rice did not vary due to seedbed preparation methods. However, weedy check treatments reduced more than 92.78 % of grain yield of dry-direct seeded rice compared to weed-free check. The herbicidal treatments were found to be superior for the benefit-cost ratio. Pendimethalin fb Bispyribac sodium recorded the highest net returns of NRs 68.73 thousand $ha^{-1}$ and the benefit-cost ratio of 2.55. Sequential application of Pendimethalin followed by Bispyribac sodium was proved to be the most efficient weed management method for dry-direct seeded rice.

**Keywords**: Direct seeded rice, benefit-cost ratio, seedbed, weed management

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## INTRODUCTION

Rice is the second most important food grain in the world in terms of production after wheat. Global rice production in 2018 was 782 million metric tons (FAOSTAT 2020). It is the main source of livelihood for the world's 2.3 billion farmers and their households and provides 20% of the world's dietary energy supply (Alexandratos and Jelle 2012). Almost 90% of the world's rice is produced and consumed in Asia and provide up to 3/4$^{th}$ of the total calorie required by Asians (Priya et al 2019).

The productivity growth of rice in Nepal in the last 54 years has not kept up with the population growth rate. Nepal's per capita rice consumption per year is 137.5 kg, one of the highest in the world, but we do not produce enough rice in the country. There is a huge rice yield gap, the difference between attainable yield and potential yield, which is between 45-55% in Nepal. It might be due to not using of high-yielding genotypes along with improved crop management practices coupled with climate change and seasonal variations (Joshi and Upadhaya 2020).

Direct seeding of rice (DSR) has evolved as a promising technology to minimize the cost of production by reducing labor and water requirement and potential alternative to the detrimental effects of puddling and transplanting. Direct seeding refers to the direct planting of rice seeds in the main field with or without puddling (Shekhawat et al 2020), which avoids transplanting operation and maintains standing water. DSR, therefore, stands strong in the areas of shortcomings of transplanted rice that helps meet challenges posed by water and labor shortage mitigating edaphic conflicts and promises fair yield. The majority of rice area is under rainfed conditions in Nepal hence, DDSR seems to be more contextual. DDSR has several advantages over transplanted rice. Kumar and Ladha (2011) reported that DDSR saves up to 60% of labor, 35% of water with a reduction in methane gas emission and cost of cultivation by 92% and 32% respectively saving about $50 per hectare, DSR crop matures 7-14 days earlier ensuring timely planting of succeeding crop.

Although DDSR seems one of the potential alternatives to puddled transplanted rice (TPR), several challenges confront the wide-scale adoption of DDSR by farmers such as weed infestation, water management, stagnant yield, unavailability of suitable varieties, nutrient availability and pests and diseases (Nguyen and Ferrero 2006), among which high weed infestation is the major bottleneck in DSR especially in dry fields (Rao et al 2007). Shift from TPR to DDSR cause drastic change in weed flora due to aerobic nature of soil, where more than 50 weed species infest direct-seeded rice, causing major losses to rice production worldwide (Rao et al 2007; Tomita et al 2003). DSR faces a potential threat from changes in the competing weed flora that are difficult to control (Johnson et al 2003). Both rice crop and weed emerge simultaneously and there is no water layer to suppress weeds in DDSR. In absence of effective weed control measures the yield penalty in DDSR was found very high often leading to a reduction in yield or no yield at all (Kim and Ha 2005; Rashid et al 2012; Busi et al 2017). Therefore, the experiment was conducted to identify the effects of seedbed preparation and weed management practices on the weed density, weed control efficiency and crop yields of dry direct seeded rice.

## MATERIALS AND METHODS

### Experimental site

The experiment was conducted in the Agronomy Research Block of Agriculture and Forestry University (AFU), Rampur, Chitwan from May to October, 2014 during the rainy season.

### Soil physico-chemical properties

The soil of experimental plot was sandy loam in texture. All other chemical properties such as soil organic matter (3.18%), total nitrogen (0.16%), available phosphorus (36.18 kg $ha^{-1}$) and available potassium (139.92 kg $ha^{-1}$) were found medium except soil pH (5.5) which was slightly acidic.

### weather conditions during experimentation

During the cop growth duration, the average maximum temperature ranged from 29.73 $^0$C (last fortnight of October) to 36.87$^0$C (during the month of May) whereas the average minimum temperature was found between 17.64$^0$C (last fortnight of October) to 26.04$^0$C (last fortnight of July). The total rainfall during the whole season was 2014.95 mm. Similarly, maximum cumulative rainfall was recorded during the first fortnight of August (492.9 mm) and there was no rainfall during the last fortnight of October. The relative humidity varied between 73.93% (first fortnight of May) and 90.96% (last fortnight of June) (Figure 1).

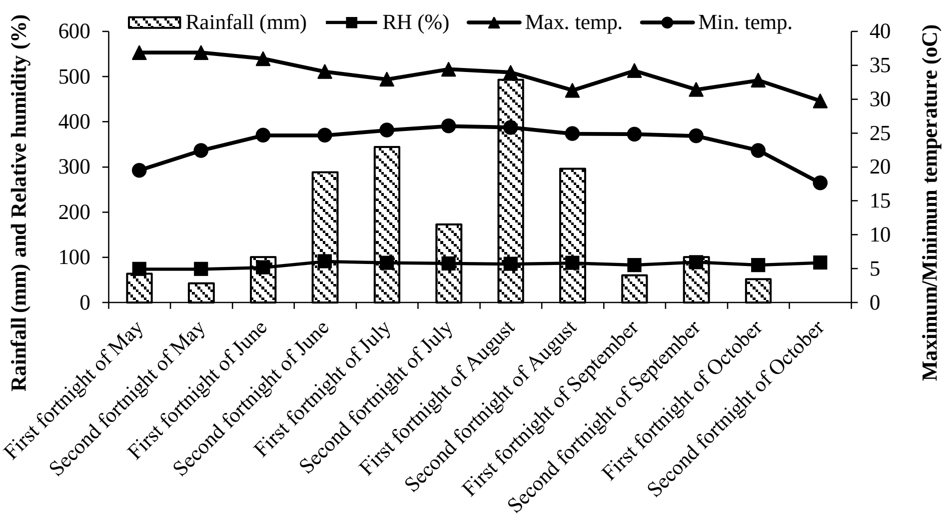


**Figure 1. Weather conditions during experimentation at AFU, Rampur Chitwan, 2014 (Source: NMRP, 2014)**

### Experimental details

The experiment was conducted in Split-plot design with the seedbed preparation methods in the main plot (Normal bed: One deep plowing followed by 3 light plowings and planking and Dry-DSR and Stale bed: One deep plowing followed by 3 light plowings and planking, irrigated the field and left for two weeks and Dry-DSR) and six different weed management practices (weedy check, weed free as per need, Pendimethalin @ 3.3 L $ha^{-1}$ followed by 2,4-D ethyl ester

@ 0.5 kg $ha^{-1}$ at 25 DAS, Bispyribac sodium @ 25 g a.i. $ha^{-1}$ applied at 22 DAS, Pendimethalin @ 3.3 L $ha^{-1}$ followed by (fb) Bispyribac sodium @ 25 g a.i. $ha^{-1}$applied at 22 DAS and Sesbania co-culture (Brown manuring) and killing Sesbania at 28 DAS with 2, 4-D ethyl ester @ 0.5 kg $ha^{-1}$ + 1HW at 45 DAS) assigned in the subplots, replicated four times. The plot size was 3 m x 3.5 m and rice variety Radha 4 was sown continuously in rows spaced 20 cm apart. All other crop management practices were followed as per recommendation.

### Economic and Statistical analysis

Costs of cultivation, gross and net returns B:C Ratio was calculated for economic analysis and statistical analysis was done using MSTAT-C software package. Means were separated by DMRT at 5% level of significance.

## RESULTS AND DISCUSSION

### Weed density and weed dry weight

The seedbed preparation methods did not influence significantly, the total weed density at different time series, except at harvest where stale seedbed significantly reduced the weed density compared to normal seedbed. However, the weed management practices significantly influenced the total weed density at each observation (Table 1).

In general, all the weed management practices significantly reduced the weed density compared to weedy check at different time series. Pendimethalin fb 2,4-D and Pendimethalin fb Bispyribac Sodium had statistically similar weed density in comparison with weed-free check and significantly lower weed density than Sesbania co-culture and sole application of Bispyribac Sodium as post-emergence at 30 DAS. Pendimethalin applied plots showed lower weed density than other treatments because Pendimethalin was applied a day after seeding which controlled many weeds but in other treatments weed density was higher. Similarly, at 45 DAS the chemical treatments and Sesbania co-culture were found statistically similar to each other in terms of weed density. The treatments Pendimethalin fb Bispyribac Sodium and Sesbania co-culture had statistically similar weed densities at 60 DAS and at harvest. Pendimethalin fb Bispyribac Sodium was effective in broad spectrum control of weeds than Pendimethalin fb 2,4-D. Sesbania co-culture was supplemented with one hand weeding at 47 DAS which reduced weed density at later observations.

**Table 1. Total weed density (number of weeds per $m^{-2}$) as influenced by seedbed preparation and weed management practices at different dates of observation in DDSR at AFU, Rampur, Chitwan, 2014**

| Treatments | Total weed density (no. of weeds $m^{-2}$) at different DAS | | | |
|---|---|---|---|---|
| | 30 | 45 | 60 | Harvest |
| **Seedbed preparation** | | | | |
| Stale seedbed | 16.14 (292.49) | 14.26 (240.11) | 11.46 (172.1) | $12.08^{b}$ (150.87) |
| Normal seedbed | 15.01 (254.10) | 13.33(212.91) | 11.91 (198.07) | $12.69^{a}$ (171.82) |
| LSD (<0.05) | ns | ns | ns | 0.57 |
| SEm(±) | 0.26 | 0.58 | 0.26 | 0.12 |
| **Weed management practices** | | | | |
| Weedy check | $24.11^{a}$ (596.19) | $23.98^{a}$ (589.82) | $26.01^{a}$ (679.4) | $17.40^{a}$ (305.23) |
| Weed free check | $11.53^{d}$ (141.69) | $6.22^{c}$ (41.07) | $6.96^{d}$ (50.13) | $9.03^{d}$ (81.42) |
| Pendimethalin fb 2,4-D EE | $11.96^{cd}$ (151.87) | $12.43^{b}$ (162.32) | $10.01^{c}$ (108.2) | $13.05^{b}$ (170.95) |
| Bispyribac Sodium | $19.46^{b}$ (385.29) | $14.64^{b}$ (219.28) | $12.46^{b}$ (157.9) | $12.73^{b}$ (163.09) |
| Pendimethalin fb Bispyribac Sodium | $11.20^{d}$ (130.89) | $11.36^{b}$ (139.28) | $8.05^{d}$ (70.16) | $10.81^{c}$ (117.85) |

| Treatments | Total weed density (no. of weeds m$^{-2}$) at different DAS | | | |
|---|---|---|---|---|
| | **30** | **45** | **60** | **Harvest** |
| Sesbania co-culture+1 HW | 15.23$^{c}$ (233.83) | 14.17$^{b}$ (207.32) | 6.63$^{d}$ (44.66) | 11.32$^{c}$ (129.52) |
| LSD (<0.05) | 3.39 | 3.06 | 1.63 | 1.26 |
| SEm (±) | 1.17 | 1.061 | 0.56 | 0.43 |
| CV (%) | 21.36 | 21.77 | 13.67 | 9.96 |
| **Grand mean** | **15.58** | **13.79** | **11.68** | **12.39** |

Note: Data subjected to square-root (√X+0.5) transformation; figures in parentheses are original data; Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance. Note: DAS (days after sowing), HW: hand weeding, Na: sodium, EE: ethyl ester, ns: non significant.

**Table 2. Total weed dry weight (g m$^{-2}$) as influenced by seedbed preparation and weed management practices at different dates of observation in DDSR at Rampur, Chitwan, 2014**

| Treatments | Total weed dry weight (no. of weeds m$^{-2}$) at different DAS | | | |
|---|---|---|---|---|
| | **30** | **45** | **60** | **Harvest** |
| **Seedbed preparation** | | | | |
| Stale seedbed | 6.48(50.96) | 8.00(79.82) | 9.08 (123.79) | 8.61(96.77) |
| Normal seedbed | 5.75(39.62) | 7.93(81.99) | 9.56 (124.81) | 9.00 (115.87) |
| LSD (<0.05) | ns | ns | ns | ns |
| SEm(±) | 0.16 | 0.19 | 0.39 | 0.17 |
| **Weed management practices** | | | | |
| Weedy check | 10.46$^{a}$ (111.98) | 14.95$^{a}$ (225.61) | 19.69$^{a}$ (389.71) | 18.98$^{a}$ (363.59) |
| Weed free check | 2.34$^{d}$ (5.18) | 1.63$^{d}$ (2.33) | 2.39$^{e}$ (5.34) | 2.47$^{d}$ (5.73) |
| Pendimethalin fb 2,4-D EE | 5.51$^{c}$ (32.36) | 7.35$^{c}$ (56.71) | 8.12$^{c}$ (69.96) | 8.62$^{b}$ (77.38) |
| Bispyribac Sodium | 8.24$^{b}$ (69.84) | 9.26$^{b}$ (88.55) | 13.71$^{b}$ (192.96) | 9.33$^{b}$ (89.03) |
| Pendimethalin fb Bispyribac Sodium | 5.24$^{c}$ (28.34) | 6.76$^{c}$ (48.59) | 7.65$^{c}$ (68.74) | 4.69$^{c}$ (21.82) |
| Sesbania co-culture+1 HW | 4.88$^{c}$ (24.05) | 7.85$^{bc}$ (63.61) | 4.37$^{d}$ (19.08) | 8.75$^{b}$ (80.37) |
| LSD (<0.05) | 1.20 | 1.55 | 1.94 | 1.17 |
| SEm (±) | 0.41 | 0.53 | 0.67 | 0.40 |
| CV (%) | 19.33 | 19.06 | 20.44 | 13.11 |
| **Grand mean** | **6.11** | **7.96** | **9.32** | **8.81** |

Note: Data subjected to square-root (√X+0.5) transformation; figures in parentheses are original data; Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance, DAS (days after sowing), HW: hand weeding, Na: sodium, EE: ethyl ester, ns: non significant.

The method of seedbed preparation did not influence the total weed dry weight (g m$^{-2}$) at different dates of observation but weed management practices significantly influenced weed dry weight at all the observations (Table 2).

All the weed management practices significantly reduced the weed dry weight compared to weedy check. The treatments Pendimethalin fb 2,4-D and Pendimethalin fb Bispyribac Sodium were statistically similar to each other and recorded lower weed dry weight after weed free check at 30 and 45 DAS than other treatments. At 60 DAS the treatment Sesbania co-culture recorded lower weed dry weight compared to all the herbicide treatments which was due to one hand weeding carried out in Sesbania co-culture plots at 47 DAS. But finally, at harvest significantly lower weed dry weight was observed in the treatment Pendimethalin fb Bispyribac Sodium after weed free check.

There was non-significant difference between normal and stale seedbed because first land preparation in both stale and normal bed was done at the same time, and there was rainfall few days after application of irrigation to stale seedbed which germinated some of the weed seeds in the normal seedbed as well. Also, the soil in stale seedbed became compacted due to application of irrigation water which required slight intensive tillage compared to normal bed. As a result, more weed seeds in lower depth were exposed and germinated in the stale seedbed which showed slightly more weed density and dry weight in initial observation which gradually declined compared to normal seedbed due to exhaustion of weed seed bank in later observations.

## Productivity of DDSR

Grain yield, straw yield and harvest index were not significantly influenced by the method of seedbed preparation but weed management practices significantly influenced all these parameters (Table 3).

**Table 3. Grain yield, straw yield and harvest index as influenced by seedbed preparation and weed management practices in DDSR at Rampur, Chitwan, 2014**

| Treatments | Grain yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) | Harvest Index |
|---|---|---|---|
| **Seedbed preparation** | | | |
| Stale seedbed | 3293.39 | 4346.72 | 0.36 |
| Normal seedbed | 3280.62 | 4014.47 | 0.39 |
| LSD (<0.05) | ns | ns | ns |
| Sem (±) | 130.21 | 191.42 | 0.01 |
| **Weed management practices** | | | |
| Weedy check | 318.51$^{c}$ | 849.4$^{d}$ | 0.23$^{b}$ |
| Weed free check | 4171.10$^{a}$ | 5150.31$^{ab}$ | 0.41$^{a}$ |
| Pendimethalin fb 2,4-D EE | 3862.49$^{ab}$ | 4695.35$^{abc}$ | 0.41$^{a}$ |
| Bispyribac Sodium | 3355.55$^{b}$ | 4589.59$^{bc}$ | 0.38$^{a}$ |
| Pendimethalin fb Bispyribac Sodium | 4157.11$^{a}$ | 5264.75$^{a}$ | 0.40$^{a}$ |
| Sesbania co-culture+1 HW | 3857.28$^{ab}$ | 4534.22$^{c}$ | 0.42$^{a}$ |
| LSD (<0.05) | 488.4 | 565.8 | 0.045 |
| SEm (±) | 169.10 | 195.90 | 0.015 |
| CV (%) | 14.55 | 13.25 | 11.24 |
| **Grand mean** | **3287.01** | **4180.60** | **0.37** |

Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance. Note: HW: hand weeding, Na: sodium, ns: non-significant

## Grain yield

Different weed management practices significantly influenced the grain yield where highest grain yield was obtained in weed free check and least in the weedy check (Table 3). Sequential application of pre and post-emergence herbicide and Sesbania co-culture gave statistically similar yields to weed free check than sole application of Bispyribac Sodium as post emergence. Sequential application of Pendimethalin fb Bispyribac Sodium produced better result of grain yield than other herbicide treatments and Sesbania co-culture. Sole application of Bispyribac Sodium and sequential application of Pendimethalin fb 2,4-D produced statistically similar grain yields to Sesbania co-culture. These findings are in line of Bhurer (2013).

## Straw yield

Among weed management practices, sequential application of pre and post-emergence herbicides recorded higher but statistical similar straw yield to weed free check (Table 3).

Highest straw yield was obtained from sequential application of Pendimethalin fb Bispyribac Sodium followed by weed free check, sequential application of Pendimethalin fb 2,4-D sole application of Bispyribac Sodium and Sesbania co-culture, respectively. The least and statistically lowest straw yield was obtained from weedy check.

## Harvest index

All the weed management practices except weedy check (0.23) gave higher harvest index and were statistically at par with each other (Table 3). The highest harvest index of 0.42 was observed in Sesbania co-culture. Sole application of Bispyribac Sodium had lower harvest index than sequential application of pre and post-emergence herbicides.

## Weed index

There was non-significant difference in the weed index due to seedbed preparation methods. However, weed management practices significantly influenced weed index (Figure 2). Significantly higher weed index (92.78%) was observed in weedy check which means there was 92.8 % reduction in yield in weedy check compared to the yield of weed free plot. There was 1.95% increment (least weed index, -1.95%) in the grain yield due to Pendimethalin fb Bispyribac Sodium compared to weed free check which was statistically at par with Pendimethalin fb 2,4-D and Sesbania co-culture. Sole application of Bispyribac Sodium had significantly higher grain yield penalty (18.21%) after weedy check.

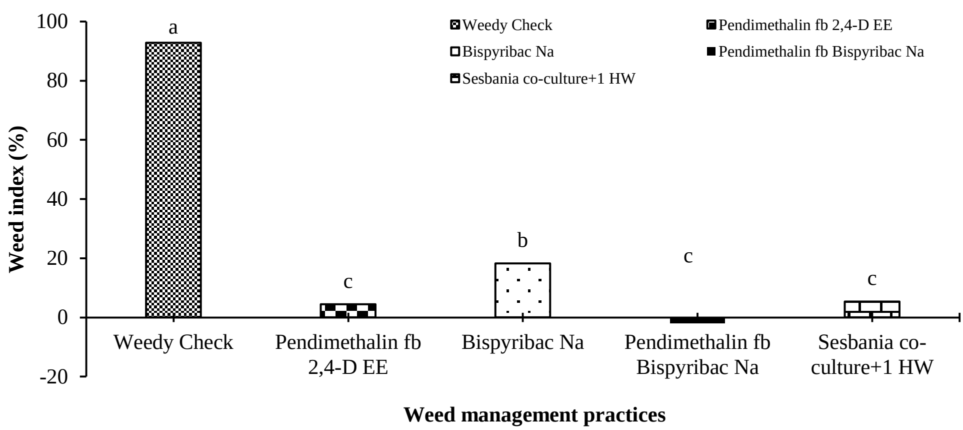


**Figure 2. Weed index as influenced by weed management practices**

## Weed control efficiency

Weed control efficiency was not significantly influenced by methods of seedbed preparation but was due to different weed management practices.

Higher weed control efficiency, statistically at par with weed free check at 30 days after seeding (DAS) was observed in the plots where Pendimethalin was applied as pre-emergence and the least in sole application of Bispyribac Sodium (Figure 3). Similar trend of weed control efficiency was observed at 45 DAS, apart from weed free check which had the highest weed control efficiency. At 60 DAS, Sesbania co-culture had the highest weed control efficiency statistically similar to weed free check and sequential application of Pendimethalin with

Bispyribac Sodium. Hand weeding at 47 DAS had increased the weed control efficiency of Sesbania co-culture at 60 DAS. Bhurer (2013) and Khaliq et al (2011) reported the similar findings.

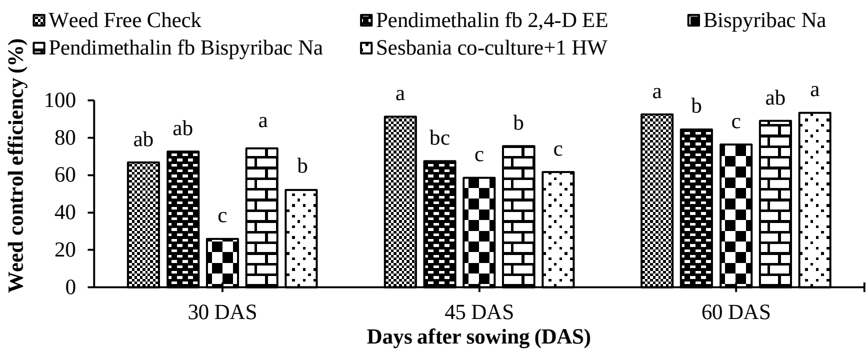


**Figure 3. Weed control efficiencies as influenced by weed management practices at different time series**

**Economics of DDSR**

Gross returns, net returns and benefit-cost ratio were not significantly influenced by seedbed preparation methods but were influenced by weed management practices (Table 4).

Among different weed management practices, the highest net returns (68.73 thousand) and BCR of 2.55 was found in the sequential application of Pendimethalin with Bispyribac Sodium followed by sequential application of Pendimethalin with 2,4-D (Table 4). Sole application of Bispyribac Sodium had statistically similar BCR with sequential application of Pendimethalin with Bispyribac Sodium, but had lower gross return. Higher cost associated with manual weeding in weed-free plots and cost of Sesbania as well as manual weeding in Sesbania co-culture resulted in a lower BCR. Bhurer (2013) also observed the highest net returns and BCR from Pendimethalin fb Bispyribac Sodium. Khaliq et al (2011) reported the highest net benefit from the sequential application of pre and post-emergence herbicides.

**Table 4. Total cost of production, gross return, net return and BCR as influenced by seedbed preparation and weed management practices in DDSR at Rampur, Chitwan, 2014**

| Treatments | Total cost NRs $ha^{-1}$ ('000) | Gross returns NRs $ha^{-1}$ ('000) | Net returns NRs $ha^{-1}$ ('000) | B:C Ratio |
|---|---|---|---|---|
| **Seedbed preparation** | | | | |
| Stale seedbed | 44.35 | 90.14 | 45.79 | 1.97 |
| Normal seedbed | 43.30 | 88.51 | 45.20 | 1.99 |
| LSD (<0.05) | - | ns | ns | ns |
| SEm(±) | - | 3.44 | 3.44 | 0.07 |
| **Weed management practices** | | | | |
| Weedy check | 35.54 | 10.46[c] | -25.08[c] | 0.29[c] |
| Weed free check | 53.04 | 112.7[a] | 59.68[ab] | 2.12[b] |
| Pendimethalin fb 2,4-D EE | 42.86 | 104.1[ab] | 61.22[ab] | 2.42[a] |
| Bispyribac Sodium | 39.47 | 92.50[b] | 53.03[b] | 2.34[ab] |

| Treatments | Total cost NRs $ha^{-1}$ ('000) | Gross returns NRs $ha^{-1}$ ('000) | Net returns NRs $ha^{-1}$ ('000) | B:C Ratio |
|---|---|---|---|---|
| Pendimethalin fb Bispyribac Sodium | 44.15 | 112.9[a] | 68.73[a] | 2.55[a] |
| Sesbania co-culture+1 HW | 47.88 | 103.3[ab] | 55.43[b] | 2.15[b] |
| LSD (<0.05) | | 11.66 | 11.66 | 0.25 |
| SEm (±) | | 4.03 | 4.03 | 0.08 |
| CV (%) | | 12.79 | 25.10 | 12.68 |
| **Grand mean** | **43.83** | **89.32** | **45.50** | **1.98** |

Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at 5% level of significance. Note: HW: hand weeding, Na: sodium, ns: non-significant

## CONCLUSIONS

Although method of seedbed preparation did not show significant differences on weed control and productivity but the results showed positive effects of stale seedbed over normal seedbed as the weed density and dry weight in stale seedbed tend to decrease in later stages of crop growth. Sequential application of Pendimethalin with Bispyribac Sodium, sequential application of Pendimethalin with 2,4-D and Sesbania co-culture followed by one hand weeding significantly reduced the weed density and dry matter compared to weedy check, but sequential application of Pendimethalin fb Bispyribac Sodium was found to be the best option for effective control of weeds producing higher grain yield and benefit cost ratio.


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## AUTHORS' CONTRIBUTION

TB Karki conceptualized and wrote this manuscript, P Gyawaly conducted the field experiment and generated necessary data and other co-authors' were involved in editing this manuscript.

## CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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