# *SESBANIA* KNOCKDOWN DAYS AND SEED RATES OF DRY DIRECT SEEDED RICE INFLUENCE WEED DYNAMICS AND PRODUCTIVITY OF RICE

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**ABSTRACT**

*In dry direct seeded rice (DDSR), weeds are the major problems limiting the productivity of crop. Sesbania co-culture with DDSR as well as seed rates of rice affect weed density by smothering effect on weeds and therefore can be a better weed management technique. Two year field experiments were conducted at Regional Agricultural Research Station, Parwanipur, Bara, Nepal from 2015 to 2016 to assess the effect of Sesbania knockdown dates and seed rates of DDSR on weed density and yield of rice. The experiment was arranged in two factorial strip plot design having four replications. The treatment comprised of four levels of seed rates of DDSR (25, 50, 75 and 100 kg ha$^{-1}$) in the vertical strips whereas four levels of Sesbania knockdown days (21, 28, 35 and 42 days after sowing (DAS)) in horizontal strip. The data on weed densities, weed biomass, yield and yield attributing characters of rice were collected and analyzed using MSTATC statistical software. The data revealed decreasing weed density with increasing days of knockdown of Sesbania. Significantly lower weed densities were recorded when Sesbania was knockdown at 42 DAS as compared with 21 and 28 DAS at all dates of observations and in both years 2015 and 2016. The weed densities at knockdown days of 35 and 42 DAS were statistically at par with each other at 45 and 105 DAS in 2016. Similarly, weed densities were significantly lower when seed rates of DDSR was increased to 75 to 100 kg ha$^{-1}$ as compared to 25 to 50 kg ha$^{-1}$ in both years at most of observation dates. Sesbania knockdown at 42 DAS recorded significantly higher grain and straw yields but was statistically similar to knockdown dates of 35 DAS. Similarly, higher seed rates of 75 to 100 kg ha$^{-1}$ produced better grain and straw yields than 25 to 50 kg ha$^{-1}$ seed rates of DDSR. The higher yield of DDSR at knockdown of Sesbania at 35 to 42 DAS and higher seed rates of 75 to 100 kg ha$^{-1}$ of DDSR was due to reduction in weed density which resulted in better yield attributes and grain yield of DDSR. Therefore, knockdown days of 35 DAS and seed rates of 75 kg ha$^{-1}$ seem better option for DDSR.*

**Keywords:** Dry Direct seeded rice, *Sesbania*, seed rate, knockdown days, weeds.

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## INTRODUCTION

Rice is the most important food crops of Nepal which accounts first position on the basis of area (1.46 million ha) and production (5.15 million ton) with the productivity of 3.50 t $ha^{-1}$ (CBS, 2018). Conventional puddled transplanted rice (CPTR) is the major system of rice production in Nepal but nowadays, there is scarcity of agricultural workers due to migration of rural labors to cities for industrial work which has resulted in scarcity of labors in rice growing season. But in Direct Seeded Rice (DSR) system, labor requirements are less and crop matures at least seven to ten days earlier as compared to CPTR system (Singh *et al.*, 2008) which ultimately facilitates timely planting of succeeding crops (Ahmed *et al.*, 2014). Despite of various advantages, the main constraints of DSR systems are weeds infestation which ultimately decrease grain yield of rice (Chauhan and Johnson, 2010; Mahajan and Chauhan, 2013)and yield reduction may go beyond 90% if weeds are not managed timely (Chauhan and Johnson, 2011). Many alternatives are available for management of weeds in DSR, the application of herbicides seems to be the most common (Mahajan*et al.*, 2014), but it can cause risk of herbicide resistance problems and environmental contamination .Therefore, Integrated Weed Management (IWM) strategies that include preventive, cultural and chemical weed control methods are desirable in DSR system (Chauhan*et al.*, 2012). Some cultural weed management method includes use of a stale seedbed method, cultivars possessing weed competitive characters, mulches and brown manuring, high seeding rates, proper sowing time and methods (Chauhan and Yadav, 2013; Kaur and Singh, 2017).

Brown manuring, is a method of seeding *Sesbania* with direct seeded rice and after 30 days, it is knockdown by applying 2,4-D @ 400-500 g $ha^{-1}$whichhas smothering effect on weeds, help to conserves oil moisture and increase nitrogen content of soil (Gill and Walia, 2014) and also reduces the density of weeds to about half of its population (Singh *et al.*, 2016). It also helps to decrease the population and biomass of weeds up to 41-56% and 62-75%, respectively as compared to crops without brown manuring (Nawaz*et al.*, 2017).

Higher seeding rate of direct seeded rice increased crop competitiveness against weeds (Chauhan and Johnson, 2011) and helps to increase grain yield in weedy condition (Phuhong *et al.*, 2005) but low seeding rate encourages the growth of weeds, and results in poor quality of grain (Singh*et al.*, 2016). In direct seeded rice crop, higher seeding rate up to 150 kg $ha^{-1}$ is used in many Asian countries like Vietnam and Sri Lanka. Likewise, higher seeding rate is also popular in South American countries but in mechanized row seeded crop (Chauhan *et al.*, 2014). Therefore, this study was initiated to assess the impact of dates of knockdown of *Sesbania* and seeding rates of rice on weed population, weed dry matter, yield attributes and yield of rice in DSR system.

## MATERIALS AND METHODS

### Experimental site

Field experiments were conducted during the rainy season of 2015 and 2016 in research block of Regional Agricultural Research Station, Parwanipur, Bara, Nepal. The geographical location of the site lies at an altitude of 120 meter above mean sea level, 27°20' N (latitude) and 84°53' E (longitude).

### Physio-chemical properties of experimental soil

Soil samples were collected randomly from different spots of experimental plot from 0-15 cm depth using tube auger and composite samples were made to record the initial physico-chemical properties of soil. The experimental plot consisted of slightly acidic (5.5) pH of soil and sandy clay loam in texture. The soil was medium in soil organic matter (3.77%), total nitrogen (0.19%), low in available phosphorus (5.77 kg $ha^{-1}$) and medium in available potassium (197.20 kg $ha^{-1}$).

**Climatic condition during experimentation**

The total annual rainfall during 2015 and 2016 were 1288.1 mm and 1270.7 mm, respectively. The rice growing season of 2015 and 2016 recorded the maximum temperature ranged from 31.93°C to 36.33°C and 31.87°C to 34.68°C, respectively while minimum temperature ranged from 20.75°C to 26.44°C and 21.65°C to 26.80°C, respectively.

**Experimental details**

The experiment was laid out in strip-plot design with four replications. The treatment consisted of four levels of *Sesbania* knockdown days (21, 28, 35 and 42 DAS) as horizontal factor whereas four seed rates of rice (25, 50, 75 and 100 kg $ha^{-1}$) as the vertical factors. The rice hybrid variety Arize 6444 was used. The fertilizer dose applied was 120:40:30 N, $P_2O_5$ and $K_2O$ kg $ha^{-1}$, respectively. The size of individual plot was 15 $m^2$. Rice was seeded manually in line having row spacing of 20 cm. The *Sesbania* was knocked down using 2, 4-D ethyl ester at the rate of 750 g a.i. $ha^{-1}$. Full amount of Phosphorus and Potassium and $1/3^{rd}$ N was applied at the time of seeding while remaining $2/3^{rd}$ nitrogen was applied at 25 DAS and 45 DAS in two equal half. Zinc sulphate @ 25 kg $ha^{-1}$ was also applied at the time of seeding.

Observation regarding the total density of weed was recorded within each plot using a quadrate having size of 0.5 m x 0.5 m at two places at 45, 75 and 105 DAS growth stage of rice and expressed as weeds $m^{-2}$ and for total weed dry matter, weed samples uprooted were oven dried at $70^0$ C till constant weight and expressed as g $m^{-2}$. The data of weed density and dry matter were subjected to square root transformation before analysis to normalize their distribution. Effective tiller $m^{-2}$was recorded from net plot area of individual plot. Length of panicle, weight per panicle and grains $panicle^{-1}$(filled and unfilled) were recorded from 20 randomly selected panicles per plot. For thousand grain weight, grains were taken from the grain yield of each net plot and weighed with the help of automatic electronic balance and expressed in gram. Grain yield was recorded from net plot area of 5.6 $m^2$ and expressed in t $ha^{-1}$ at 14% moisture content. MSTAT-C software was used for data analysis. Analysis of variance was used for all the recorded data and Duncan's multiple range test (DMRT) was applied for mean separations at $P \leq 0.05$.

**RESULTS AND DISCUSSION**

**Total weed density of DDSR**

The main weed species recorded in the experimental site were *Echinochloa coloana* L., *Eluesine indica* Gaertn, *Cynodon dactylon* (L.) Pers. and *Cyperus rotundus* L. Knock down days of *Sesbania* at 42 DAS decreased the total weed density at 45 DAS of rice in both years 2015 and 2016. It was statistically similar with knockdown dates of 35 DAS but significantly lower than knockdown dates of 21 and 28 DAS in both years (Table- 1). During later stages, knockdown days of *Sesbania* at 42 DAS decreased the total weed density at 75 DAS during both years 2015 and 2016 while it was also statistically similar with knockdown dates of 28 and 35 DAS in 2015. At 105 DAS, knockdown days of *Sesbania* at 42 DAS decreased the total weed density during both years 2015 and 2016 and it was also statistically similar with knockdown dates of 28 and 35 DAS in 2015 while it was statistically similar with 35 DAS in 2016. It was observed that with an increase in knockdown days from early to late i.e.21 to 42 DAS, weed density decreased by 49 and 43% at 45 DAS, while it was 32 and 47% at 75 DAS and 47 and 50% at 105 DAS in 2015 and 2016, respectively. Lower weed density with late knockdown days was mainly attributed to more growth of *Sesbania* producing higher canopy coverage and more mulching material for controlling weeds. Sharma (2013) from Rampur, Chitwan, Nepal also reported significantly lowest values of total weed density from knockdown days of 35 DAS at 40 DAS of rice. Likewise, Mohtisham*et al.*(2013) from Pakistan reported that at 40 DAS of rice, intercropping of *Sesbania* with direct seeded rice recorded lowest values of broadleaf and narrow leaf weed densities.

Increasing seed rate of DDSR from 25 to 100 kg ha$^{-1}$decreased the total weed density significantly and was also statistically similar with seed rates of 75 kg ha$^{-1}$ in both years at all the growth stages of rice (Table-1). Increased seed rates of DDSR from 25 to 100 kg ha$^{-1}$, decreased total weed density by 34 and 33% at 45 DAS, while it was 26 and 30% at 75 DAS and 39 and 37% at 105 DAS in 2015 and 2016, respectively. Low seeding rates of rice created favorable environment for early germination and rapid growth and development of weeds while higher seeding rates reduced growth of weeds by closing canopy earlier (Phuhong *et al.*, 2005; Ahmed *et al.,* 2014). In another study, Khaliq *et al.* (2012) reported greater weed suppression in aerobic rice from using seed rate of 75 kg ha$^{-1}$ in comparison to 50 kg ha$^{-1}$. Likewise, Ahmed *et al.*(2014) from Bangladesh also reported decreased total weed density by 38 and 47% at 35 DAS while it was 40 and 65% at anthesis stage when seed rate of direct seeded rice increased from lower seed rate of 20 kg ha$^{-1}$to higher seed rate of 100 kg ha$^{-1}$in 2012 and 2013, respectively. Imran *et al.* (2016) reported that as seed rate increased a linear decreased was observed in weed density.

**Total weed dry matter of DDSR**

Knockdown days of *Sesbania* at 42 DAS significantly decreased the total weed biomass of DDSR during both years 2015 and 2016 at all the growth stages of rice, however, at 105 DAS, it was also statistically similar with knockdown days of 35 DAS during 2016 (Table-2). With increase in knockdown days from 21 to 42 DAS, weed dry matter decreased by 33 and 30% at 45 DAS, while it was 32 and 47% at 75 DAS and 47 and 50% at 105 DAS in the 2015 and 2016, respectively. Lower total weed dry matter with late knockdown days was mainly due to more growth of *Sesbania* produced more mulching material and suppressed weed growth and reduced weed biomass. Sharma (2013) also reported lowest weed dry matterof dry dire ct seeded rice from late knockdown days of *Sesbania* at 35 DAS as compared to knockdown days of 15 and 25 DAS at 40 and 60 DAS stage of rice. Kumari and Tarun deep (2016) reported lower weed density of direct seeded rice from knockdown days of *Sesbania* at 28 and 35 DAS which were statistically similar to each other.

Increasing seed rate of DDSR from 25 to 100 kg ha$^{-1}$decreased the total weed dry matter significantly in both years 2015 and 2016 at all the growth stages of rice and it was statistically similar with seed rates of 75 kg ha$^{-1}$at 45 DAS in 2016 while at 75 DAS during both years (Table-2).Increased seed rates of DDSR from 25 to 100 kg ha$^{-1}$, weed dry matter decreased by 35 and 31% at 45 DAS, while it was 39 and 24% at 75 DAS and 37 and 42% at 105 DAS in the 2015 and 2016, respectively. Lower weed dry matter with higher seeding rate of rice was due to smothering effect of rice on weeds and thus reducing weed growth. Chauhan (2013) observed higher weed dry matter of direct seeded rice with lower seeding rate of 50 kg ha$^{-1}$ as compared to higher seeding rate of 100 kg ha$^{-1}$ at harvesting stage of rice. Similarly, Ahmed *et al.*(2014) reported significantly decreased weed biomass by 54 and 56% at 35 DAS and 41 and 60% at an thesis stage of direct seeded rice when seed rate of rice increased from 20 to 100 kg ha$^{-1}$ during 2012 and 2013, respectively. Likewise, Sharma and Singh (2010) reported significantly decreased dry matter accumulation of weeds with increasing seed rates of DDSR from 75 to 150 kg ha$^{-1}$.

Table-1. Total weed density (no. $m^{-2}$) as influenced by *Sesbania* knockdown days and seed rates of DDSR at RARS, Parwanipur, Bara, Nepal during 2015 and 2016.

| **Treatments** | **Total weed density (No. $m^{-2}$)** | | | | | |
|---|---|---|---|---|---|---|
| | **45 DAS** | | **75 DAS** | | **105 DAS** | |
| | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** |
| **Knockdown days** | | | | | | |
| 21 DAS | 11.30$^{a}$ (133.90) | 12.47$^{a}$ (157.90) | 12.50$^{a}$ (160.30) | 14.47$^{a}$ (215.30) | 7.88$^{a}$ (68.13) | 9.82$^{a}$ (100.90) |
| 28 DAS | 9.62$^{b}$ (95.69) | 11.33$^{a}$ (135.00) | 10.64$^{ab}$ (117.00) | 12.54$^{b}$ (161.40) | 6.14$^{ab}$ (41.75) | 7.76$^{b}$ (63.25) |
| 35 DAS | 7.31$^{c}$ (56.88) | 8.76$^{b}$ (80.00) | 9.04$^{b}$ (84.56) | 9.62$^{c}$ (95.69) | 5.37$^{b}$ (30.88) | 5.71$^{c}$ (33.75) |
| 42 DAS | 5.75$^{c}$ (34.81) | 7.14$^{b}$ (54.63) | 8.51$^{b}$ (77.00) | 7.73$^{d}$ (63.38) | 4.14$^{b}$ (17.31) | 4.93$^{c}$ (25.25) |
| $LSD_{0.05}$ | 1.66 | 2.07 | 2.05 | 1.36 | 1.96 | 1.03 |
| SE | 0.51 | 0.64 | 0.64 | 0.42 | 0.61 | 0.32 |
| **Seed rates of rice** | | | | | | |
| 25 kg $ha^{-1}$ | 10.41$^{a}$ (119.10) | 12.13$^{a}$ (151.40) | 11.68$^{a}$ (141.40) | 13.55$^{a}$ (193.90) | 7.31$^{a}$ (59.56) | 8.88$^{a}$ (86.94) |
| 50 kg $ha^{-1}$ | 8.91$^{b}$ (85.94) | 10.38$^{b}$ (115.10) | 10.74$^{ab}$ (121.30) | 11.31$^{b}$ (137.30) | 6.48$^{ab}$ (46.88) | 7.45$^{b}$ (60.69) |
| 75 kg $ha^{-1}$ | 7.75$^{c}$ (64.69) | 9.02$^{c}$ (87.00) | 9.67$^{bc}$ (98.56) | 10.03$^{c}$ (108.10) | 5.26$^{bc}$ (29.81) | 6.30$^{c}$ (42.88) |
| 100 kg $ha^{-1}$ | 6.92$^{c}$ (51.56) | 8.16$^{c}$ (74.00) | 8.59$^{c}$ (77.63) | 9.46$^{c}$ (96.38) | 4.49$^{c}$ (21.81) | 5.59$^{c}$ (32.63) |
| $LSD_{0.05}$ | 0.89 | 1.00 | 1.48 | 1.24 | 1.27 | 0.74 |
| SE | 0.27 | 0.31 | 0.46 | 0.38 | 0.39 | 0.23 |
| CV % | 17.90 | 14.37 | 13.94 | 14.22 | 22.83 | 16.28 |
| Grand mean | 8.49 | 9.92 | 10.17 | 11.09 | 5.88 | 7.06 |

Square-root ($\sqrt{X+0.5}$) transformation of data; original values are presented in parenthesis; Means followed by the same letter (s) within a column are non-significantly different based on DMRT at $P \leq 0.05$; DAS: Days after seeding.

Table-2. Total weed dry biomass (g $m^{-2}$) as influenced by *Sesbania* knockdown days and seed rates of DDSR at RARS, Parwanipur, Bara, Nepal during 2015 and 2016.

| **Treatments** | **Total weed dry biomass (g $m^{-2}$)** | | | | | |
|---|---|---|---|---|---|---|
| | **45 DAS** | | **75 DAS** | | **105 DAS** | |
| | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** |
| **Knockdown days** | | | | | | |
| 21 DAS | $11.21^{a}$ (130.60) | $11.39^{a}$ (134.20) | $14.88^{a}$ (233.20) | $14.58^{a}$ (217.60) | $9.08^{a}$ (85.25) | $9.78^{a}$ (100.50) |
| 28 DAS | $10.02^{b}$ (104.40) | $10.99^{ab}$ (124.70) | $11.71^{b}$ (144.50) | $12.23^{b}$ (153.70) | $7.97^{b}$ (67.50) | $8.48^{b}$ (77.07) |
| 35 DAS | $9.13^{c}$ (85.19) | $9.59^{b}$ (97.88) | $9.00^{c}$ (87.38) | $10.99^{b}$ (122.30) | $6.86^{c}$ (48.75) | $7.63^{bc}$ (60.59) |
| 42 DAS | $7.53^{d}$ (59.75) | $7.99^{c}$ (67.01) | $7.01^{d}$ (51.75) | $8.86^{c}$ (80.98) | $5.44^{d}$ (31.44) | $6.62^{c}$ (46.47) |
| $LSD_{0.05}$ | 0.86 | 1.48 | 1.58 | 1.59 | 0.89 | 1.27 |
| SE | 0.27 | 0.46 | 0.49 | 0.49 | 0.27 | 0.39 |
| **Seed rates of rice** | | | | | | |
| 25 kg $ha^{-1}$ | $11.38^{a}$ (132.10) | $12.03^{a}$ (149.50) | $13.37^{a}$ (195.30) | $13.33^{a}$ (186.90) | $9.00^{a}$ (84.06) | $10.52^{a}$ (112.90) |
| 50 kg $ha^{-1}$ | $10.31^{a}$ (109.10) | $10.75^{a}$ (117.80) | $11.66^{a}$ (150.40) | $12.14^{ab}$ (153.00) | $8.13^{b}$ (69.19) | $8.67^{b}$ (77.19) |
| 75 kg $ha^{-1}$ | $8.82^{b}$ (82.19) | $8.89^{b}$ (83.86) | $9.40^{b}$ (98.38) | $11.06^{bc}$ (128.30) | $6.51^{c}$ (45.50) | $7.18^{c}$ (54.77) |
| 100 kg $ha^{-1}$ | $7.37^{c}$ (56.50) | $8.30^{b}$ (72.59) | $8.17^{b}$ (72.81) | $10.14^{c}$ (106.50) | $5.70^{d}$ (34.19) | $6.13^{d}$ (39.70) |
| $LSD_{0.05}$ | 1.17 | 1.38 | 1.72 | 1.32 | 0.72 | 0.64 |
| SE | 0.36 | 0.43 | 0.53 | 0.41 | 0.22 | 0.20 |
| CV % | 14.60 | 16.81 | 19.98 | 14.75 | 20.42 | 18.14 |
| Grand mean | 9.47 | 9.99 | 10.65 | 11.66 | 7.34 | 8.13 |

Square-root ($\sqrt{X+0.5}$) transformation of data; original values are presented in parenthesis; Means followed by the same letter (s) within a column are non-significantly different based on DMRT at $P \leq 0.05$; DAS: Days after seeding

**Yield attributes of DDSR**

Knockdown days of *Sesbania* at 42 DAS recorded the highest values of effective tillers $m^{-2}$, panicle length and grains per panicle in both years 2015 and 2016. It was statistically similar with knockdown days of 35 DAS but significantly better than knockdown days of 21 and 28 DAS in both years (Table-3). Higher number of effective tillers and larger panicle length under these treatments were due to the lower weed competition, which resulted crops to absorb required amount of nutrients and moisture for its growth and development with higher tillering behaviour. Early knockdown of *Sesbania* produced lower growth and lesser canopy coverage causing higher weed crop competition and produced lesser values of effective tillers of plants. Higher values of grains per panicle with the late knockdown might be due to release of more amount of nitrogen than that of knockdown of *Sesbania* within short duration. Marhatta *et al.* (2017) also reported highest values of grains per panicle of direct seeded rice from *Sesbania* knockdown days of 28 DAS which was also statistically similar with knockdown days of 35 DAS and 42 DAS. Similarly, increasing knockdown days increased the weight per panicle significantly and it was the highest when knockdown days were 42 DAS. Lower density and dry matter of weeds caused lesser weed-crop competition providing the favourable environment for growth and development of crop which ultimately increased values of weight per panicle in these treatments. Similarly, sterility % decreased significantly with knockdown days of 35-42 DAS as compared to 21-28 DAS.

Increasing seed rates of rice from 25 to 100 kg $ha^{-1}$improved the values of effective tillers $m^{-2}$ significantly in both years 2015 and 2016 whereas values of grains per panicle also increased with increasing seed rates but it was significant only in 2015 and at par among seed rates in 2016 (Table-3). Ahmed *et al.* (2014) also reported significantly increased panicle numbers (effective tillers) of direct seeded rice when seeding rate increased from lower seed rate of 20 kg $ha^{-1}$to higher seed rate of 100 kg $ha^{-1}$ under partially weed infested condition and panicle number was increased by 26 and 47% at 100 kg seed $ha^{-1}$incomparisonto panicle number at 20 kg seed $ha^{-1}$ in 2012 and 2013, respectively. But under weedy condition, Chauhan *et al.* (2011) observed increased number of panicles in quadratic relation with increase in seed rate of direct seeded rice from 15-125 kg $ha^{-1}$. Similarly, increased seed rate of rice from 25 to 100 kg $ha^{-1}$ increased the weight per panicle significantly in 2016 and at par among one another during 2015.*Sesbania* knockdown days and seed rates of DDSR did not significantly influenced the thousand grain weight. Similar result was also reported by Sharma and Singh (2010) and Singh *et al.* (2017) in dry direct seeded rice but seed rates used was from 40 to 150 kg $ha^{-1}$.

Table-3. Yield attributes as influenced by *Sesbania* knockdown days and seed rates of DDSR at RARS, Parwanipur, Bara, Nepal during 2015 and 2016.

| Treatment | Effective tiller $m^{-2}$ | | Panicle length (cm) | | Grains $panicle^{-1}$ | |
|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| **Knockdown days** | | | | | | |
| 21 DAS | 231.10$^{c}$ | 205.30$^{c}$ | 23.34$^{c}$ | 22.94$^{b}$ | 153.80$^{b}$ | 150.60$^{b}$ |
| 28 DAS | 244.90$^{b}$ | 219.60$^{bc}$ | 24.69$^{b}$ | 23.25$^{b}$ | 159.50$^{ab}$ | 156.10$^{b}$ |
| 35 DAS | 254.40$^{ab}$ | 235.30$^{ab}$ | 25.51$^{a}$ | 23.54$^{ab}$ | 164.90$^{ab}$ | 160.80$^{ab}$ |
| 42 DAS | 268.20$^{a}$ | 255.40$^{a}$ | 25.94$^{a}$ | 24.09$^{a}$ | 181.40$^{a}$ | 180.80$^{a}$ |
| $LSD_{0.05}$ | 18.83 | 22.72 | 0.68 | 0.68 | 21.98 | 21.93 |
| SE | 5.88 | 7.10 | 0.21 | 0.21 | 6.87 | 6.85 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Seed rates of rice** | | | | | | |
| 25 kg ha$^{-1}$ | 214.90$^{b}$ | 182.10$^{d}$ | 24.83 | 23.23 | 155.70$^{b}$ | 155.50 |
| 50 kg ha$^{-1}$ | 235.80$^{b}$ | 215.80$^{c}$ | 24.87 | 23.41 | 162.10$^{ab}$ | 158.50 |
| 75 kg ha$^{-1}$ | 262.70$^{a}$ | 241.80$^{b}$ | 24.96 | 23.55 | 169.30$^{ab}$ | 165.80 |
| 100 kg ha$^{-1}$ | 285.30$^{a}$ | 275.90$^{a}$ | 24.82 | 23.63 | 172.50$^{a}$ | 168.40 |
| $LSD_{0.05}$ | 23.56 | 12.25 | ns | ns | 14.88 | ns |
| SE | 7.36 | 3.82 | 0.16 | 0.14 | 4.65 | 3.97 |
| CV% | 9.88 | 12.23 | 3.53 | 3.66 | 12.46 | 13.43 |
| Grand mean | 249.65 | 228.87 | 24.86 | 23.45 | 164.88 | 162.06 |

Means followed by the same letter (s) within a column are non-significantly different based on DMRT at P≤ 0.05; DAS: Days after seeding.

Table-4. Yield attributes as influenced by *Sesbania* knockdown days and seed rates of DDSR at RARS, Parwanipur, Bara, Nepal during 2015 and 2016.

| **Treatment** | **Wt. per panicle (g)** | | **1000-grain weight (g)** | | **Sterility %** | |
|---|---|---|---|---|---|---|
| | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** |
| **Knockdown days** | | | | | | |
| 21 DAS | 3.27$^{c}$ | 3.07$^{c}$ | 22.37 | 22.10 | 13.67$^{a}$ | 13.88$^{a}$ |
| 28 DAS | 3.41$^{b}$ | 3.31$^{b}$ | 22.50 | 22.15 | 12.54$^{ab}$ | 12.76$^{ab}$ |
| 35 DAS | 4.30$^{a}$ | 3.47$^{b}$ | 22.68 | 22.38 | 11.64$^{b}$ | 11.80$^{b}$ |
| 42 DAS | 4.39$^{a}$ | 3.81$^{a}$ | 22.64 | 22.96 | 11.43$^{b}$ | 11.62$^{b}$ |
| $LSD_{0.05}$ | 0.12 | 0.23 | ns | ns | 1.18 | 1.18 |
| SEm | 0.03 | 0.07 | 0.10 | 0.48 | 0.36 | 0.36 |
| **Seed rates of rice** | | | | | | |
| 25 kg ha$^{-1}$ | 3.82 | 3.22$^{b}$ | 22.46 | 22.12 | 11.92 | 12.13 |
| 50 kg ha$^{-1}$ | 3.81 | 3.36$^{ab}$ | 22.52 | 22.03 | 12.06 | 12.26 |
| 75 kg ha$^{-1}$ | 3.88 | 3.47$^{ab}$ | 22.60 | 22.48 | 12.64 | 12.82 |
| 100 kg ha$^{-1}$ | 3.87 | 3.60$^{a}$ | 22.62 | 22.95 | 12.66 | 12.85 |
| $LSD_{0.05}$ | ns | 0.26 | ns | ns | ns | ns |
| SE | 0.03 | 0.08 | 0.10 | 0.32 | 0.29 | 0.28 |
| CV% | 3.23 | 8.56 | 2.37 | 6.54 | 10.00 | 10.10 |
| Grand mean | 3.84 | 3.41 | 22.54 | 22.39 | 12.31 | 12.51 |

Means followed by the same letter (s) within a column are non-significantly different based on DMRT at P≤ 0.05; DAS: Days after seeding.

**Grain yield, straw yield and harvest index of DDSR**

Knockdown days of *Sesbania* at 42 DAS recorded significantly highest values of grain and straw yield in both years 2015 and 2016. It was statistically similar with knockdown dates of 35 DAS but significantly better than knockdown durations of 21 and 28 DAS in both years (Table-5). Yield attributing characteristics of rice viz. effective tillers, grains panicle$^{-1}$and, panicle weight were responsible for the increased grain yield of rice. Likewise, late knocking of *Sesbania* produced higher biomass of *Sesbania* which released large amount of nitrogen, contributing more to yield attributing characters of rice and produced higher yield of rice as compared to early knockdown days. In case of wet direct seeded rice, late incorporation of *Sesbania* at 37 DAS recorded higher grain yield of rice (Ravisankar *et al.*, 2008). Similarly, Anitha and Mathew (2010) reported higher grain yield of wet seeded rice from late incorporation of *Sesbania* at 30 DAS as compared to early incorporation of 20 DAS. However, Marhatta *et al.* (2017) reported optimum knockdown days of *Sesbania* as nearly 32 DAS based on polynomial regression between knockdown days of *Sesbania* with grain yield in DDSR. Harvest index was significantly higher with knockdown days of *Sesbania* at 42 DAS which was statistically similar with knockdown days of 35 DAS but significantly better than knockdown dates of 21 and 28 DAS in 2015 and at par among each other during 2016.

Increasing seed rates of rice from 25 to 100 kg ha$^{-1}$ significantly increased grain and straw yield of rice in both years and it was the highest at seeding rate of 100 kg ha$^{-1}$ which was also statistically similar with 75 kg ha$^{-1}$ in case of grain yield. Higher seeding rates of rice decreased the weed density and biomass which caused lower weed-crop competition providing the favorable environment for crop growth and development. Sharma and Singh (2010) also observed significantly highest grain and straw yield of direct seeded rice from the seed rate of 100 kg ha$^{-1}$andreported decreased grain and straw yield when seed rate was further increased to 125 and 150 kg ha$^{-1}$.Dongarwar *et al.* (2018) reported that among the seed rates of direct seeded rice (50, 75, 100, 125 and 150 kg ha$^{-1}$), highest grain yield was recorded from the seed rate of 50and 75kg ha$^{-1}$which was statistically at par with each other and there was decrease in yield with further increase in seed rate.In another study by Ahmed *et al.* (2014) reported that with increase in seeding rate from 20 to 100 kg ha$^{-1}$, grain yield of DDSR increased by 30-33% under partially weeded condition during 2012 and 2013. However, 17-19% increase in grain yield of direct seeded rice was reported by Chauhan (2013) from higher seeding rate of 100 kg ha$^{-1}$ as compared to lower seeding rate of 50 kg ha$^{-1}$.In weedy condition, increased seeding rates of direct seeded rice from 15 to 125 kg ha$^{-1}$ increased grain yield in quadratic relation as reported by Chauhan *et al.* (2011) and further suggested to use seeding rate of 83-92 kg ha$^{-1}$ for the hybrid varieties and 95-125 kg ha$^{-1}$ for inbred varieties to achieve maximum yields. Increasing seed rates of rice to 100 kg ha$^{-1}$ increased harvest index percentage significantly from 25 kg ha$^{-1}$ in 2015 and was at par among each other during 2016.

Table-5. Grain yield, straw yield and harvest index as influenced by *Sesbania* knockdown days and seed rates of DDSR at Parwanipur, Bara, Nepal during 2015 and 2016.

| Treatment | Grain Yield (t ha$^{-1}$) | | Straw Yield (t ha$^{-1}$) | | Harvest Index (%) | |
|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| **Knockdown days** | | | | | | |
| 21 DAS | 5.12$^{b}$ | 4.48$^{c}$ | 8.03$^{b}$ | 7.39$^{c}$ | 38.34$^{c}$ | 35.06 |
| 28 DAS | 5.29$^{b}$ | 5.10$^{b}$ | 8.50$^{b}$ | 8.36$^{b}$ | 39.34$^{bc}$ | 36.44 |
| 35 DAS | 5.63$^{ab}$ | 5.51$^{ab}$ | 8.86$^{ab}$ | 9.02$^{ab}$ | 40.15$^{ab}$ | 38.04 |
| 42 DAS | 6.11$^{a}$ | 5.80$^{a}$ | 9.46$^{a}$ | 9.16$^{a}$ | 41.39$^{a}$ | 38.80 |
| $LSD_{0.05}$ | 0.50 | 0.51 | 0.88 | 0.69 | 1.53 | ns |
| SE | 0.15 | 0.16 | 0.27 | 0.21 | 0.47 | 1.13 |
| **Seed rates of rice** | | | | | | |
| 25 kg ha$^{-1}$ | 4.96$^{c}$ | 4.54$^{c}$ | 7.96$^{c}$ | 7.39$^{d}$ | 38.44$^{c}$ | 35.42 |
| 50 kg ha$^{-1}$ | 5.47$^{b}$ | 5.03$^{b}$ | 8.33$^{c}$ | 7.79$^{c}$ | 39.35$^{bc}$ | 36.83 |
| 75 kg ha$^{-1}$ | 5.85$^{a}$ | 5.61$^{a}$ | 8.96$^{b}$ | 8.91$^{b}$ | 40.38$^{ab}$ | 38.04 |
| 100 kg ha$^{-1}$ | 5.88$^{a}$ | 5.71$^{a}$ | 9.59$^{a}$ | 9.83$^{a}$ | 41.07$^{a}$ | 38.05 |
| $LSD_{0.05}$ | 0.31 | 0.28 | 0.48 | 0.23 | 1.25 | ns |
| SE | 0.09 | 0.08 | 0.15 | 0.07 | 0.39 | 0.97 |
| CV% | 13.66 | 11.73 | 6.94 | 7.21 | 4.04 | 9.68 |
| Grand mean | 5.54 | 5.22 | 8.71 | 8.48 | 39.80 | 37.08 |

Means followed by the same letter (s) within a column are non-significantly different based on DMRT at P≤ 0.05; DAS: Days after seeding.

## CONCLUSIONS

*Sesbania* knockdown days of 35 to 42 DAS and higher seeding rates of 75 to 100 kg ha$^{-1}$significantly decreased the weed density and weed dry matter of DDSR which has a major constraint in direct seeded rice. This practice is more advantageous for farmers to minimize the cost of manual weeding and the use of herbicides which can creates herbicide resistance in weeds and environmental contamination. Brown manuring also conserves soil moisture and reduce chemical nitrogen requirement of crops. Therefore, it is recommended for the farmers that knockdown days of 35 DAS and seed rates of 75 kg $ha^{-1}$ seem better option for higher yield of DDSR.

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