***Original Research Article***

**INFLUENCED OF INTEGRATED NITROGEN AND WEED MANAGEMENT PRACTICES ON CROP-WEED COMPETITION AND NUTRIENT DEPLETION IN DIRECT SEEDED RICE**

**ABSTRACT**

A trial was conducted during 2019-20 and 2020-21 at BHU, Varanasi, to study the effect of integrated nitrogen and weed management on weeds in dry direct seeded rice. The main plot treatments consisted of four nitrogen management practices *viz.* Control (only P and K), RDF (100% RDN through inorganic), 75% RDN (Inorganic) + 25% through FYM, 75% RDN (Inorganic) + 25% through Vermicompost whereas five weed management practices *viz.* wheat residue as mulch (4 t ha-1) *fb* bispyribac Na 25 g *a.i.* ha-1 (2-4 leaf stage of weed), Pendimethalin 1 kg *a.i.* ha-1 *fb* bispyribac Na 25 g *a.i.* ha-1 (2-4 leaf stage of weed), *Sesbenia* up to 30 days (Brown manuring), Two hand weeding (20 and 40 DAS) and Weedy check were allocated to subplots and replicated thrice. The maximum weed control efficiency was recorded with the control (only P and K) whereas 75% N through inorganic + 25% by FYM being statistically comparable with 75% N through inorganic + 25% by VC and 100% N from inorganic registered the lowest weed control efficiency. However, significantly lower weed index was noticed with the application of 75% N through inorganic + 25% by VC which was followed by 75% N through inorganic + 25% by FYM, 100% N from inorganic and control. In case of nutrient removal by weeds, significantly maximum nutrient content and depletion by weeds was noticed in N2 (75% RDN (inorganic) + 25% through FYM) over control nevertheless it remained statistically at par with N3 (75% RDN (inorganic) + 25% through VC) and N1 (100% RDN through inorganic). Among integrated weed management options, hand weeding at 20 and 40 DAS showed superiority over all the weed management practices. Application of wheat residue as mulch (4 t ha-1) *fb* bispyribac Na 25 g *a.i.* ha-1 (2-4 leaf stage of weed) recorded distinctly higher weed control efficiency and lowest weed index followed by Pendimethalin 1 kg *a.i.* ha-1 *fb* bispyribac Na 25 g *a.i.* ha-1. Nutrient content and removal by weed were lowest in wheat residue as mulch (4 t ha-1) *fb* bispyribac Na 25 g *a.i.* ha-1 (2-4 leaf stage of weed), whereas, it was recorded highest in weedy check.

**Key words** Direct seeded rice, FYM, NPK, weed control efficiency, weed index

**INTRODUCTION**

Rice (*Oryza sativa* L.) is a second most important cereal crop after wheat grown widely over 161 million ha in more than 100 countries in the world(FAO, 2020). It is the staple food crop for people in South, Southeast, and East Asia, which produce and consume approximately 90% of the global rice (FAO, 2017). India is the second largest rice producer in the world next to China, which occupies an area of 43.2 Mha (million hectare) and produces 110.15 Mt (million tonnes) with a productivity of 2550 kg ha-1 (GOI, 2018). However, the projected demand for rice will be 121.2 million tonnes by 2030 and 137.3 million tonnes by 2050 for internal consumption only. To fulfil the requirement, the productivity of rice has to be brought to the level of 3.3 tonnes ha-1, which is only 2.4 tonnes at present (CRRI, 2013).

Direct seeded rice has several advantages over puddled transplanted rice. However, certain biotic and abiotic stresses challenge the widespread adoption of DSR. Among all biotic constraints, weeds and nutrient are the major obstacles that reduce productivity, profitability as well as the sustainability of DSR (Chauhan 2012b). The magnitude of the problem can be ascertained with the following examples *ie*., in India, about 33% of rice yield losses are caused by weeds (Mukherjee, 2004), while in Sri Lanka, weeds accounted for 30-40% of yield losses (Abeysekera, 2001). Globally, rice production, about 10% of the total yield is reduced by weeds (Oerke and Dehne, 2004). Despite, yield losses, weeds also deplete plant nutrients from soil in large quantity have been reported by many researcher (Brar and Bhullar, 2013). Therefore, effective and prompt weed management is essential for higher productivity in DSR. This, in turns requires a good understanding about critical period of crop-weed competition. The critical period of crop-weed competition represents the time interval between the two distinct components: (i) the length of time crop must be free of weed after planting so that later-emerging weeds do not reduce yield, and (ii) the length of time weeds which emerge with the crop can remain before they begin to interfere with crop growth (Ghosheh et al., 1996). Weed interference beyond “critical period” had a little or negligible effect on crop yield. Therefore, weed management during “critical period” is crucial to avoid substantial losses in crop yield (Weaver, 1984). This may be achieved by removing weed at the commencement of the crop-weed competition or keeping the crop weed free until the end of the critical period (Woolley et al., 1993). Adoption of multi tactics approach for weed management is the better option for sustainable production of direct seeded rice. Keeping these facts in view, the present investigation was carried out to study the effect of integrated nitrogen and weed management on weeds in dry direct seeded rice.

**MATERIALS AND METHODS**

The field trial was conducted during the kharif season (June to October) 2019-20 and 2020-21 to study the effect of different weed and nitrogen management practices on crop- weed competition in direct seeded rice. The experiment was laid out at Agricultural Research Farm, Banaras Hindu University, Varanasi (50 18'N latitude and 880 03'E longitude, 76 m AMSL) under an assured irrigation facility. The region falls under a semi-arid to sub- humid climate, having a mean annual rainfall and potential evapotranspiration (PET) of 1102.4 mm and 1550 mm, respectively, with a moisture deficit index ranging between -20 to -40. The experimental site was homogeneous in fertility with levelled topography, uniform textural class (sandy clay loam) classified as Typic Ustochrept. A proper channel was provided in order to meet crop water requirements and remove the excess water, if any, during the investigation. The field of the trial remained the same during both years of investigation. The initial Physico-chemical properties of the experimental site were low in available nitrogen (172.25 kg ha-1) and medium in available phosphorus (14.76 kg ha-1) and potassium (196.36 kg ha-1).

The experiment was laid out in split plot design comprising of four integrated nitrogen management *viz*., N0 Control (only P and K), N1 (100% RDN inorganic), N2 (75% RDN through Inorganic + 25% through FYM), N3 (75% RDN (Inorganic) + 25% through Vermicompost) in main plots and five weed management practices *viz.,* W0 (Weedy check), W1 (Two hand weeding at 20 and 40 DAS), W2 (*Sesbania* co-culture up to 30 days), W3 (wheat straw mulching 4 t ha-1 *followed by* bispyribac Na 25 g a.i. ha-1 at 2-4 leaves stage of weed), and W4 (pendimethalin 1 kg a.i. ha-1 at pre-emergence (PE) *fb* bispyribac Na at 25 g a.i. ha-1 at 2-4 leaves stage weed) in subplots and replicated thrice. Rice variety HUR-105 was sown in lines at a seed rate of 60 kg ha-1 at 20 cm row spacing with solid row planting on 17th and 26th July in 2019 and 2020, respectively. The required quantities of fertilizers were calculated separately as per recommended dose (150-60-60-25kg NPKZn ha-1)and applied in the form of urea, single super phosphate, muriate of potash and zinc sulphate, respectively for each plot. The quantity of FYM and vermicompost was calculated on the basis of their nitrogen content on dry weight basis separately for each treatment. Half dose of nitrogen and full doses of P, K and Zn were applied at the time of sowing. The rest half of the nitrogen was divided in two equal splits and top dressed at maximum tillering and panicle initiation stage in the form of urea. The required amount of pre-emergence and post-emergence herbicides was sprayed as per the treatment using spray volume of 600 litres of water ha-1 with the help of knap sack sprayer fitted with flat fan nozzle.

The weed samples were collected and levelled according to the treatments for chemical estimation of N, P and K content. The collected samples were dried in oven at 70 ± 5 ℃ for 48 hours and then grounded thoroughly in a grinder and pass through 40 mesh sieves with all due care of any admixture. The powdered samples were collected in zipped polythene bags with marks and numbering for identification and used for chemical analyses. Nitrogen, phosphorus, potassium, content in crops and weeds were analyzed as per standard procedure (Table 1)-

**Table 1.** Methods of plant chemical analysis

|  |  |  |
| --- | --- | --- |
| Nutrient | Analytical method | References |
| Nitrogen | Micro Kjeldahl method | Jackson (1973) |
| Phosphorus | Vanado molybdate yellow colour method | Jackson (1973) |
| Potassium | Flame photometer method | Jackson (1973) |

Nutrient removal by weeds were calculated in kg ha-1 in relation to weed dry matter production (kg ha-1) by using the following formula:

Weed control efficiency (WCE) was calculated on basis of weed biomass in various treatments as suggested by Mani *et al*. (1973).

Where,

WDMC = Weed biomass (g m-2) in control plot

WDMt = Weed biomass (g m-2) in treated plot

**Weed index**

The weed index was calculated as a percentage of difference between grain yield between the treated and weed free plots (Gill and Kumar, 1969).

Where,

WI = Weed Index

X = Grain yield (kg ha-1) from weed free plot

Y = Grain yield (kg ha-1)from treated plot

**RESULTS AND DISCUSSION**

**Weed control efficiency (%)**

Weed control efficiency implies the relative efficacy of weed management interventions compared to the weedy check. Under different nitrogen sources, higher weed control efficiency was recorded in N0 (only P and K) during both years (Table 2). This might be attributed to the fact that nitrogen play a significant role in promoting weed germination and growth and therefore, deficiency of nitrogen in the treatment led to less weed density as well as dry matter accumulation by weeds. Malecka and Blecharczyk (2008) who worked in barley opined that nitrogen application influence weeds density and dry matter accumulation. The minimum weed control efficiency was found in N2 (75% RDN (inorganic) + 25% through FYM) which was statistically comparable to N3 (75% RDN (inorganic) + 25% through VC) and N1 (100% nitrogen through inorganic) at all stage of observation during each year of study. This might have happened due to more weed density and dry matter accumulation in FYM applied plot. In addition, weeds have combined competitive characteristics such as high nitrogen use efficiency, high growth rate and luxury consumption with high photosynthetic rate. These results corroborate to the findings of Singh *et al.,* 2016; Choubey *et al.*, 1998 and Ampong-Nyarko and De Datta, 1993.

Amongst weed management practices, hand weeding (20 and 40 DAS) recorded significantly maximum weed control efficiency compared to all the weed management treatments. It was due to lesser weed dry matter in manual weeding. The higher weed control efficiency in manual weeding methods also reported by Kumar *et al.* (2012) and Yogananda *et al.* (2019). At 20 DAS, the highest weed control efficiency was recorded in W4 (pendimethalin 1 kg a.i. ha-1 PE *fb* bispyribac Na 25 g a.i. ha-1 at 2-4 leaves stage of weed) which was statistically at par with W3 (wheat straw mulching 4 t ha-1 *fb* bispyribac Na 25 g a.i. ha-1 at 2-4 leaves stage of weed) but superior than other treatments. The result can be explained with the fact that pre-emergence application of pendimethalin inhibited weeds gemination, reduced weed density and dry matter accumulation of weeds. Chongtham *et al.* (2015) also have reported that pendimethalin application as per-emergence controlled initial weeds flush and their dry matter accumulation. Application of treatment W3 (wheat straw mulching 4 t ha-1 *fb* bispyribac Na 25 g a.i. ha-1 at 2-4 leaves stage of weed) accounted for significantly maximum weed control efficiency over other weed management practices, except, W4 (pendimethalin 1 kg a.i. ha-1 PE *fb* bispyribac Na 25 g a.i. ha-1 at 2-4 leaves stage of weeds). This might be due to lower weed dry matter accumulation in this treatment. The release of allelochemicals from mulch, reductions in light transmittance, and fluctuations in thermal amplitude by the residue cover have been known to reduce the emergence of many weeds (Teasdale and Möhler 1993). The presence of residue cover may not only decrease weed emergence but also delay weed seed germination. It could be concluded that late-emerging weeds are likely to face greater competition for resources from the crop that might reduce dry matter accumulation (Chauhan and Johnson 2010b). Combination of bispyribac in this treatment, further provides synergy due to reduction in dry weight accumulation of weeds emerged above the crop residue. Chouhan and Abugho (2013) observed that the combination of mulch and herbicide spray reduced weed biomass compared to using herbicide alone.

**Weed index**

Weed index is an ideal measure of crop yield reduction due weed infestation in comparison with weed free plots reported by Suria *et al.* (2011). The data presented in table 2 as affected by different integrated sources of nitrogen and weed management practices for both year of observation.

Among integrated nitrogen sources, a lower weed index was recorded in N3 (75% RDN (inorganic) + 25% through VC) which might be due to lesser crop-weed competition as indicated by minimum weed dry weight in this treatment, thus the grain yield of direct seeded rice was least affected. The minimum weed index value in this treatment may be attributed to higher grain yield. The use of organic manure in combination with inorganic sources provides balance nutrient to the plants which led to higher growth and yield attributes and the final yield of the crop. All other treatments recorded minimum weed index values as compared to N0 (only Pand K). This might be due to a lack of nitrogen which has a significant role in promoting crop growth and development, resulting reduction in rice grain yield.

All the weed control treatments noticed a significant reduction in weed density and weed dry matter in comparison to the weedy check resulting in a lower weed index. Two hand weeding at 20 and 40 DAS recorded least weed index than other treatments during both years of study. Lower weed index under this treatment, most probably due to minimum crop-weed competition, lower dry weight accumulation of weeds and better weed control efficiency as a result grain yield was least affected by weeds. The findings of scientists indicated that hand weeding at critical stages, helped prevent yield loss due to weeds (Yogananda *et al.,* 2019 and Saravanane *et al.,* 2016). This was followed by W3 (wheat straw mulching 4 t ha-1 *fb* bispyribac Na 25 g a.i. ha-1 at 2-4 leaves stage of weed). The lower weed index in this treatment might be due to the lower weed density and dry matter accumulation and higher weed control efficiency. Consequently, higher grain yield of rice. These results corroborated the finding of Fazil *et al.* (2022) who had opined that post-emergence application of herbicide control escaped weeds and reduces yield loss. Moreover, all the weed management practices had lower weed index values in comparison to the weedy check. The maximum weed index observed under weedy check might be due to maximum weeds growth throughout the crop growth cycle, leading to intense weed competition for resources and hence minimum yield (Mishra *et al.,* 2016 and Yogananda *et al.,* 2019).

**Nutrient content (%) and removal**

Nutrients (N, P and K) content (Table 3) and removal by weeds (Table 4) were significantly affected due to integrated nitrogen and weed management practices at 60 and 80 DAS during both year of investigation. Nutrient removal is a function of N, P and K content in weed and weed dry weight. The weeds grow relatively faster than crop plants and absorb available nutrients earlier, and deplete nutrient from the soil resulting in decreased availability of nutrients to crop. In general, nutrient content in weeds found in the trends of potassium > nitrogen > phosphorus. It was evident from the data that the minimum nutrients (N, P and K) content and depletion was recorded in N0 (only P and K) might be due to minimum dry matter of weed in this treatment and nutrient removal is known to be directly correlated to weed dry matter accumulation. Moreover, significantly maximum nutrient content and depletion by weeds was noticed in N2 (75% RDN (inorganic) + 25% through FYM) over control nevertheless it remained statistically at par with N3 (75% RDN (inorganic) + 25% through VC) and N1 (100% nitrogen through inorganic) considerably due to higher weed density and dry matter of weeds (Borah *et al.,* 2015).

In case of weed management practices, it was noticed that significantly lowest nutrients (N, P, K) were removed by weed in two hand weeding treatment (W1) at both stages of crop. Moreover, among other weed management options minimum nutrient depletion by weeds was caused in treatment W3 (wheat straw mulching 4 t ha-1 *fb* bispyribac Na 25 g a.i. ha-1 at 2-4 leaves stage of weed) followed by *Sesbania* brown manuring (W2) and comparable with pendimethalin 1 kg a.i. ha-1 as PE *fb* bispyribac Na 25 g a.i. ha-1 at 2-4 leaves stage of weed (W4) at 60 and 80 DAS during each year of observation. At both the stages of observation the maximum loss of nitrogen was found in weedy check (W0) during both years.

**CONCLUSION**

Base on the above findings it can be concluded that nitrogen and weed management both are crucial in direct seeded rice for sustainable rice production. Use of 25% nitrogen through vermicompost + 75% nitrogen through chemical fertilizer and wheat straw residue mulch 4 t ha-1 followed by bispyribac Na might be a good option for better weed control and nutrient utilization of crop in eastern Uttar Pradesh.

**Table 2.** Effect of integrated nitrogen and weed management practices on weed control efficiency and weed index in direct seeded rice

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | WCE (%) | | | | | | | | WI | |
| 20 DAS | | 40 DAS | | 60 DAS | | 80 DAS | |
| 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
| Nitrogen Management | | | | | | | | | | |
| N0 - Control (RDF of P2O5 and K2O) | 57.80 | 56.55 | 58.25 | 58.10 | 49.54 | 48.51 | 47.27 | 49.74 | 26.57 | 25.87 |
| N1 - RDN (150-60-60 kg NPK ha-1) | 47.47 | 47.35 | 52.96 | 52.05 | 44.40 | 43.00 | 41.69 | 42.91 | 10.59 | 13.58 |
| N2 - 75% RDN (Inorganic) +25% FYM | 43.50 | 44.07 | 48.97 | 48.22 | 40.78 | 39.67 | 37.40 | 38.61 | 7.53 | 10.59 |
| N3 - 75% RDN (Inorganic)+25% Vermicompost | 46.19 | 45.85 | 51.37 | 50.53 | 42.95 | 41.35 | 39.87 | 40.19 | 4.47 | 7.00 |
| Weed management | | | | | | | | | | |
| W0 - Weedy check | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 34.44 | 37.33 |
| W1 - Two hand weeding (20 and 40 DAS) | 100.00 | 100.00 | 100.00 | 100.00 | 72.35 | 70.79 | 71.29 | 71.42 | 0.00 | 0.00 |
| W2 - *Sesbenia* up to 30 days (30 DAS 2,4-D 0.5 kg a.i. ha-1) | 33.52 | 34.04 | 38.70 | 36.60 | 35.12 | 34.12 | 27.67 | 29.74 | 14.08 | 17.29 |
| W3 - Wheat residue as mulch (4 t ha-1) *fb* bispyribac sodium 25 g a.i. ha-1 (2-4 leaf stage of weed) | 53.63 | 52.83 | 64.20 | 63.86 | 58.23 | 56.29 | 55.64 | 57.73 | 5.14 | 7.90 |
| W4 - Pendimethalin 1 kg a.i. ha-1 *fb* bispyribac sodium 25 g a.i. ha-1 (2-4 leaf stage of weed) | 56.55 | 55.40 | 61.53 | 60.65 | 56.40 | 54.46 | 53.19 | 55.42 | 7.79 | 8.77 |

**Table 3.** Effect of integrated nitrogen and weed management practices on nutrient content in weeds in direct seeded rice

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | Nitrogen (%) | | | | Phosphorus (%) | | | | Potassium (%) | | | |
| 60 DAS | | 80 DAS | | 60 DAS | | 80 DAS | | 60 DAS | | 80 DAS | |
| 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
| Integrated Nitrogen Management | | | | | | | | | | | | |
| N0 - Control (RDF of P2O5 and K2O) | 1.51 | 1.57 | 1.90 | 1.98 | 0.191 | 0.199 | 0.410 | 0.423 | 1.69 | 1.86 | 2.44 | 2.43 |
| N1 - RDN (150-60-60 kg NPK ha-1) | 1.66 | 1.78 | 2.06 | 2.18 | 0.212 | 0.220 | 0.449 | 0.461 | 1.84 | 2.08 | 2.59 | 2.66 |
| N2 - 75% RDN (Inorganic) +25% FYM | 1.78 | 1.92 | 2.20 | 2.35 | 0.230 | 0.238 | 0.482 | 0.497 | 1.97 | 2.26 | 2.72 | 2.85 |
| N3 - 75% RDN (Inorganic)+25% Vermicompost | 1.70 | 1.84 | 2.10 | 2.24 | 0.222 | 0.229 | 0.458 | 0.480 | 1.90 | 2.16 | 2.65 | 2.74 |
| SEm± | 0.04 | 0.05 | 0.04 | 0.05 | 0.006 | 0.006 | 0.010 | 0.011 | 0.04 | 0.05 | 0.04 | 0.06 |
| CD (P=0.05) | 0.15 | 0.18 | 0.15 | 0.18 | 0.019 | 0.020 | 0.033 | 0.037 | 0.15 | 0.19 | 0.15 | 0.21 |
| Weed management | | | | | | | | | | | | |
| W0 - Weedy check | 1.85 | 2.08 | 2.25 | 2.49 | 0.261 | 0.261 | 0.514 | 0.530 | 2.05 | 2.32 | 2.80 | 2.90 |
| W1 - Two hand weeding (20 and 40 DAS) | 1.49 | 1.53 | 1.89 | 1.94 | 0.176 | 0.184 | 0.387 | 0.403 | 1.66 | 1.88 | 2.41 | 2.45 |
| W2 - *Sesbania* up to 30 days (30 DAS 2,4-D 0.5 kg *a.i.* ha-1) | 1.74 | 1.91 | 2.14 | 2.32 | 0.225 | 0.241 | 0.474 | 0.489 | 1.93 | 2.19 | 2.68 | 2.76 |
| W3 - Wheat residue as mulch (4 t ha-1) fb bispyribac sodium 25 g a.i. ha-1 (2-4 leaf stage of weed) | 1.60 | 1.66 | 2.01 | 2.07 | 0.196 | 0.204 | 0.429 | 0.444 | 1.78 | 2.01 | 2.53 | 2.59 |
| W4 - Pendimethalin 1 kg a.i. ha-1 *fb* bispyribac sodium 25 g a.i. ha-1 (2-4 leaf stage of weed) | 1.63 | 1.71 | 2.04 | 2.12 | 0.209 | 0.217 | 0.445 | 0.461 | 1.82 | 2.05 | 2.57 | 2.63 |
| SEm± | 0.03 | 0.04 | 0.03 | 0.04 | 0.005 | 0.005 | 0.007 | 0.009 | 0.03 | 0.04 | 0.03 | 0.04 |
| CD (P=0.05) | 0.09 | 0.12 | 0.09 | 0.12 | 0.013 | 0.014 | 0.020 | 0.026 | 0.09 | 0.12 | 0.09 | 0.12 |
| Interaction | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

**Table 4.** Effect of integrated nitrogen and weed management practices on nutrient removal by weeds in direct seeded rice

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | Nitrogen (kg ha-1) | | | | Phosphorus (kg ha-1) | | | | Potassium (kg ha-1) | | | |
| 60 DAS | | 80 DAS | | 60 DAS | | 80 DAS | | 60 DAS | | 80 DAS | |
| 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
| Integrated Nitrogen Management | | | | | | | | | | | | |
| N0 - Control (RDF of P2O5 and K2O) | 29.31 | 34.76 | 24.85 | 30.13 | 3.82 | 4.39 | 5.45 | 6.41 | 32.82 | 40.38 | 31.82 | 36.25 |
| N1 - RDN (150-60-60 kg NPK ha-1) | 35.56 | 42.71 | 29.89 | 37.47 | 4.64 | 5.35 | 6.60 | 7.91 | 39.21 | 49.56 | 37.32 | 44.91 |
| N2 - 75% RDN (Inorganic) +25% FYM | 40.35 | 48.69 | 33.96 | 42.91 | 5.31 | 6.05 | 7.56 | 9.11 | 44.45 | 56.66 | 41.93 | 51.49 |
| N3 - 75% RDN (Inorganic)+25% Vermicompost | 37.18 | 45.69 | 31.31 | 40.14 | 4.97 | 5.71 | 6.93 | 8.60 | 41.36 | 52.71 | 39.26 | 48.29 |
| SEm± | 1.28 | 1.72 | 0.78 | 1.05 | 0.16 | 0.17 | 0.22 | 0.28 | 1.30 | 1.86 | 0.89 | 1.24 |
| CD (P=0.05) | 4.44 | 5.96 | 2.69 | 3.65 | 0.56 | 0.59 | 0.75 | 0.96 | 4.50 | 6.44 | 3.06 | 4.27 |
| Weed management | | | | | | | | | | | | |
| W0 - Weedy check | 68.92 | 84.50 | 54.45 | 72.12 | 9.68 | 10.57 | 12.46 | 15.32 | 76.16 | 94.27 | 67.75 | 83.82 |
| W1 - Two hand weeding (20 and 40 DAS) | 15.40 | 18.11 | 13.16 | 16.06 | 1.82 | 2.19 | 2.70 | 3.34 | 17.18 | 22.37 | 16.77 | 20.32 |
| W2 - *Sesbania* up to 30 days (30 DAS 2,4-D 0.5 kg *a.i.* ha-1) | 42.10 | 51.08 | 37.63 | 47.27 | 5.46 | 6.45 | 8.32 | 9.96 | 46.75 | 58.66 | 47.07 | 56.34 |
| W3 - Wheat residue as mulch (4 t ha-1) fb bispyribac sodium 25 g a.i. ha-1 (2-4 leaf stage of weed) | 24.98 | 29.47 | 21.61 | 25.42 | 3.07 | 3.64 | 4.63 | 5.46 | 27.67 | 35.78 | 27.19 | 31.73 |
| W4 - Pendimethalin 1 kg a.i. ha-1 *fb* bispyribac sodium 25 g a.i. ha-1 (2-4 leaf stage of weed) | 26.60 | 31.65 | 23.15 | 27.45 | 3.41 | 4.01 | 5.06 | 5.95 | 29.56 | 38.04 | 29.15 | 33.97 |
| SEm± | 1.22 | 1.49 | 0.84 | 1.12 | 0.12 | 0.13 | 0.17 | 0.21 | 1.23 | 1.53 | 0.93 | 1.21 |
| CD (P=0.05) | 3.53 | 4.30 | 2.41 | 3.22 | 0.34 | 0.37 | 0.48 | 0.61 | 3.55 | 4.40 | 2.69 | 3.48 |
| Interaction | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

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