Plant Archives Vol. 25, Supplement 1, 2025 pp. 1009-1017 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.137

WEED MANAGEMENT IN DIRECT SEEDED RICE USING DIFFERENT HERBICIDE COMBINATIONS AND THEIR EFFECT ON GROWTH AND YIELD PARAMETERS

Sheetal Singh[1*], Deepak Kumar Maurya[1], Monalisa Sahoo[1], Pradumn Kumar Mourya[1], Shubham Singh[2] and Jatin Kumar Singh[3]

[1]Institute of Agriculture and Natural Sciences, D.D.U. Gorakhpur University Gorakhpur, U.P., India
[2]National Post Graduate College, Barahalganj, Gorakhpur, U.P., India
[3]G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India
*Corresponding author Email. singhsheetalss1111@gmail.com
(Date of Receiving : 21-08-2024; Date of Acceptance : 16-10-2024)

ABSTRACT

The study was conducted at Institute of Agriculture and Natural Sciences in *Kharif* season. The experiment was laid out in a randomized block design with three replications. The experiment comprised ten weed-control treatments, Pendimethalin 1.0 Kg/ha, Pendimethalin 1.0 Kg/ha +1Hand weeding, Bispyrac Sodium 25 gm/ha + (Chlorimuronethyl + Metsulfuron methyl 20gm/ha, Bispyrac Sodium 25gm/ha + Ethoxysulfuron 18 gm/ha, Bispyrac Sodium 25 gm/ha+2,4-D Ethyl Ester EC 1.0 Kg/ha, Fenoxaprop-p-ethyl 60 gm/ha + (Chlorimuron- ethyl + Metsulfuron methyl 20 gm/ha, Fenoxaprop-p-ethyl 60 gm/ha + Ethoxysulfuron 18 gm/ha, Fenoxaprop-p-ethyl 60 gm/ha + 2,4-D Ethyl Ester EC 1.0 Kg/ha, 2 Hand weeding and Control. All herbicide combinations significantly influenced weed growth and crop yield. Monocot weeds, particularly sedges, were the most dominant among all the species. Combined applications of ready-mix herbicides provided better weed control with a higher weed-control index (WCI) in DSR. The economics of the different treatments were also determined to find the best herbicide combinations suited for weed management in rice crop. Growth parameters such as plant height and number of tillers per plant, were recorded at different stages of growth. The observations recorded showed that Bispyrac sodium + (Metsulfuronmethyl + Chlorimuronethyl) increased the yield per hectare, as compared to the other herbicide combinations. These treatments have successful weed control that increased the amount of nutrients available to the rice plant, which in turn helped to promote cell division and promoted meristematic activity, boosting leaf surface area, and photosynthesis increased as leaf surface area increased.

Keywords **:** Evaluation, Herbicide, Post-emergence, Rice, Weeds.

Introduction

Rice (*Oryza sativa* L.) is an important cereal crop of Asia and other parts of the world and provides food security and livelihood for millions of farmers and workers. It is referred to as "Global grain" (Balai *et al.,* 2013) and is the primary source of nutrition for over 60% of the world's population. It is a member of the Poaceae family (Bista, 2018). According to Muthayya *et al.* (2014), Asian countries grow almost 90% of the world's rice. The adaptation method of rice mainly depends on various factors such as soil type, topography climatic conditions, and availability of irrigation water. The rice crop that is grown under rainfed upland situation is sown either by dry broadcasted after receiving the first shower of rains or wet seeding of sprouted seed in the puddled soil. In response to rising worker costs wet direct planting has become popular in many Southeast Asian nations. Dry direct seeding, is the best option to conventional practice for maintaining rice production in regions where labour and irrigation water are in short supply (Pandey and Velasco, 2002). Direct-seeded rice has quickly replaced traditional seeding throughout the years. In direct-seeded rice, conditions are much more favourable for the germination of weeds, which competes for nutrients, moisture, sunlight, and space

with rice causing larger yield losses. The most dominant weed flora in the direct-seeded rice *Echinochloa colona*, *Digitaria sanguinalis* (L.), *Commelina communis*, *Digera arvensis*, and *Caesulia axillaris*. (Mahajan *et al.,* 2013). Weed competition is very serious during the early growth stages (15-30 DAS) yield in direct seeded rice is often lower than the traditionally planted rice principally owing to the poor crop stand and high weed infestation. Moreover, the cost for weed control is in DSR is much higher than TPR. High weed infestation is a major constraint for large-scale adoption of DSR (Rao *et al.,* 2007). (DSR) production has replaced transplanted rice farming in some South East Asian nations in recent years (Pandey and Velasco 2002). Globally, 23% of rice is currently direct-seeded (*Rao et al.,* 2007). Weeds are the main biological constraint to the production of DSR (Chauhan *et al.,* 2012). Heavy weed infestation is one of the main obstacles to DSR cultivation, especially in dry field circumstances, since it results in severe production losses (Rao *et al.,* 2007). The weed flora changes dramatically, when farmers change from TPR to DSR. More than 50 weed species infest direct-seeded rice, causing major losses to rice production worldwide (Rao *et al.,* 2007). Different grasses, broadleaf weeds, and sedges have been seen to become competitive and cause significant losses to direct-seeded rice. Several pre-emergence and post-emergence herbicides are effective in managing weeds in rice established by different methods (Rao *et al.,* 2015). In order to effectively manage grassy, broadleaf, and sedge weeds in direct-seeded rice, multiple post-emergence herbicides must be tried individually, in tank combinations, or in conjunction with pre-emergence herbicides (Singh *et al.,* 2010). Pendimethalin, bispyrac sodium, fenoxaprop, and other herbicides are useful for controlling grasses and broadleaf weeds in DSR but are ineffective against sedges, especially *Cyperus rotundus*. In order for pre-emergence herbicides to be effective, rice requires a very small treatment window and constant water stagnation. The application of herbicides in the early growth phases is frequently not practical due to various constrains at the farm level, and repeated use of the same herbicide may result in weed resistance. In this case, post-emergence herbicides are an additional choice (Puniya *et al.,* 2007). When other weeds are controlled, sedges become very competitive with the DSR crop. Several herbicides, including 2, 4-D, bensulfuron, metsulfuron methyl, and metsulfuron+chlorimuron, have been reported to be successful at controlling broadleaf weeds and sedges in puddle transplanted rice. These herbicides need to be tested in the DSR system. When other weeds are controlled, sedges become very competitive with the DSR crop. In order to effectively control broadleaf weeds and sedges in direct-seeded rice, post-emergence herbicides need to be tried. Keeping the points in mind the studies were performed to study the effect of herbicide combination on weed flora, growth and yield of direct seeded rice in rainfed conditions and the economics of the treatments.

Materials and Methods

The experiment was conducted at the Hirapoori research farm, within the campus of the Institute of Agricultural and Natural Sciences, at Deen Dayal Upadhyaya Gorakhpur University Gorakhpur, during the *kharif* season 2022. The topography of the field was regular and the field was left fallow during previous years. The site falls 87 meters above the mean sea level at 26 0 45' North latitude and 830 21' East longitude and lies in a sub-tropical continental climate. The climate of Gorakhpur is characterized by a hot summer and general dryness throughout the year except during the South-West monsoon. the soil of experimental plot was clayey in texture, medium in organic carbon, neutral in reaction, low in available nitrogen and phosphorus and fairly high in available potassium, with the pH of 7.57. On July 15, 2022, '*BPT-5204*' (Days to Maturity: 140-145) was directly sown in moist soil using 120 kg of seed/hectare spaced 20 cm apart by a single row seed drill. Using a tractor-drawn cultivator, well-rotten farmyard manure equivalent to 4 tonnes/hectare was incorporated into the soil. Three equal splits of 120 kg/ha of nitrogen (N) were applied using urea at 2, 5, and 9 weeks after sowing. At the time of field preparation, a total of 60 kg/ha $ZnSO_4$ (zinc sulphate heptahydrate 21%), 60 kg/ha P (in the form of Single Super Phosphate), 40 kg/ha K (in the form of Muriate of Potash) and 30 kg/ha $ZnSO_4$ (were applied as a basal dose). Three sprays of 0.5% $FeSO_4$ were applied at weekly intervals starting 15 days after seeding to correct an iron shortage. Total ten treatments were used during the experimental period which are replicated thrice *viz.,* Pendimethalin (30EC) 1.0 Kg/ha (3-4 DAS), Pendimethalin (30EC) 1.0 Kg/ha. (3-4 DAS) +1 Hand Weeding at (25 DAS), Bispyrac Sodium 25 gm/ha + (Chlorimuronethyl + Metsulfuron methyl 20gm/ha. (20-25 DAS), Bispyrac sodium 25 gm/ha + Ethoxysulfuron, 18 gm/ha. (20-25 DAS), Bispyrac sodium 25 gm/ha + 2,4-D Ethyl Ester EC 1.0 Kg/ha (20-25 DAS), Fenoxaprop-p-ethyl 60 gm/ha + (Chlorimuron- ethyl+ Metsulfuron methyl 20 gm/ha (20-25 DAS), Fenoxaprop-p-ethyl 60gm/ha + Ethoxysulfuron 18 gm/ha (20-25 DAS), Fenoxaprop-p-ethyl 60 gm/ha + 2,4-D Ethyl Ester EC 1.0 Kg/ha. (20-

25 DAS), 2 Hand weeding at 25 & 45 DAS and Control. The plant population was recorded after 30 days, Plant height, Number of tillers, Panicles were recorded on randomly selected five plants per plot at 30, 60, 90 DAS and at harvest for preharvest studies for post-harvest studies all the above-mentioned parameters and other such as Test weight (g), Grain yield (kg/ha), Straw yield (kg/ha), Crop biomass (kg/ha), Harvest index (HI) were recorded on randomly selected five plants per plot. For weed studies Weed population (per m^2), Weed dry matter (per m^2), Weed Index (%), Weed control efficiency (%) were recorded according to the general method.

Harvest Index (%) = $\frac{Economic\ yield}{Biological\ yield} \times 100$

Where, as Economic yield = Grain yield (kg/ha)

Biological yield = Grain yield+ straw yield (kg/ha)

Weed index = $\frac{X-Y}{X} \times 100$

Where, X = Crop yield of weed free

Y= Crop yield of particular treatment

Weed control efficiency = $\frac{Wc-Wt}{Wc} \times 100$

Where, W_c = weed Dry weight per unit area in control (unweeded) plot

W_t = weed Dry weight per unit area in treatment plot

Result and Discussion

Weed Flora

Echinochloa colonum, Parthanium sp., Paspalum sp., Setaria sp., Cynodon dactylon, and *Panicum sp.* were the most prevalent grassy weeds, followed by *Cyperus rotundus* and *Cyperus esculentus* for sedges, and *Digera arvensis, Celasia argentia, Eclipta alba*, and *Euphorbia hirta Echinochloa sp.* and *Cynodon dactylon* as broad leaf weeds.

Growth parameters

Plant population

The plant population per m^2 has been recorded at 15 DAS, at this stage treatment wise and further the data was subjected for the statistical analysis. The data as mentioned in the Table 1 shows that the plant population has not differ or deviate significantly, as under the given various treatments. Its value ranged from 79.00 to 83.00 per m^2 being lowest in Control to being highest in 2 Hand weeding. The fact that there are no statistically significant differences between the populations of plants suggests that seeds that were healthy and viable were sown uniformly in all plots. All of the treatments had uniform seed germination and seeding emergence. This information shows that the chemical fertilizer that has applied below in the identical furrows where the seedlings were sown had no negative effects.

Plant height (cm)

At 30 DAS, due to the application of different treatments the plant height at the very early stage of plant growth was non-significant Table 1. The treatments pendimethalin recorded the higher plant height, which was at par with control. whereas 2 hand weeding and bispyrac sodium+ (chlorimuron+ metsulfuron) records the lower plant height that is non-significant. The data indicates that at 60 DAS stage, the plant height had significant difference due to result of various applied treatments. The treatment fenoxaprop-p-ethyl+ethoxysulfuron has recorded maximum height which was at par with control and pendimethalin. While, significantly the lower plant height was noted from (2 hand weeding) which was at par with bispyrac sodium+ (chlorimuron+metsulfuron). At harvest stage, the different weed control methods had significantly affected the plant height, the treatment control recorded the maximum height which was at par with treatments fenoxaprop-p-ethyl+2,4-D ethyl ester, pendimethalin and fenoxaprop-p-ethyl+ethoxysulfuron. The treatments 2 hand weeding recorded the lower plant height which was at par with treatment bispyrac sodium+(metsulfuron+chlorimuton) and treatment bispyrac sodium+ 2,4-D ethyl ester.

Number of tillers (per m^2)

At 30 DAS, the number of tillers were counted per square metre for each treatment, and the data obtained were subjected to statistical analysis. The mean data has been shown in Table 1, demonstrates that the various treatments had a considerable effect on the growth parameter. The treatments 2 hand weeding has recorded significantly higher tiller which was at par with treatment (bispyrac sodium+(metsulfuron+ chlorimuron), over the remaining treatments. However, treatment (bispyrac sodium+ethoxysulfuron) followed it equally, further treatment pendimethalin+1 hand weeding, (Fenoxaprop-p-ethyl +Ethoxysulfuron), (Bispyrac sodium + Ethoxysulfuron,), (Fenoxaprop-p-ethyl +2,4-D Ethyl ester) and (Bispyrac sodium +2,4-D Ethyl ester) followed it. the treatment (pendimethalin) has significantly lower tiller which was at par with treatment (control).

At 60 DAS, the data as mentioned in Table 1 indicates that the effect of different treatments upon

this parameter was continued to be significant. The treatments (2 hand weeding) recorded significantly higher tillers which was as par with treatment, (Bisyrac sodium + (Metsulfuron+Chlorimuron) over the remaining other treatments. Therefore, treatment (Bispyrac sodium + Ethoxysulfuron) also followed this, successively treatment (Pendimethalin+ 1 Hand Weeding), (Fenoxaprop-p-ethyl+ (Metsulfuron + clorimuron), (Bispyrac sodium +2,4-D Ethyl ester) and (Fenoxaprop-p ethyl +Ethoxysulfuron) followed equally. It was further lowered down in (pendimethalin) treatment (control) has significantly lowest tillers.

The increase in growth parameters was ultimately caused by the plant's ability to absorb nutrients from the soil, which led to increased root and shoot development, more green leaves, which produced more food material, more cell division, larger cells, and finally rapid growth in a shorter amount of time. The findings presented here are in strong agreement with those of numerous researchers (Katiyar and Kolhe 2006; Tiwari *et al*., 2006; and Khaliq *et al*., 2011). Regarding the effects of the treatments, it was discovered that (Bispyrac sodium + (Metsulfuron + Chlorimuron) and (Bispyrac sodium + Ethoxysulfuron considerably increased plant height as well as tiller formation per square metre at every stage of observations. These treatments have successful weed control that increased the amount of nutrients available to the rice plant, which in turn helped to promote cell division and promoted meristematic activity, boosting leaf surface area, photosynthesis increased as leaf surface area increased. The larger sink effectively affected the photosynthesis, which took the form of higher dry matter accumulation with taller tillers. The results of the current study closely align with those of numerous other researchers (Maity and Mukharjee, 2009; Thakur *et al*. 2011; Ramachandiran *et al*. 2012; Mahajan and Chauhan, 2013; and Chauhan *et al*. 2015).

Yield attributing characteristics

Number of panicles (per m^2)

The numbers of the panicles were counted per square metre, and the data resulted has been statistically calculated and then shown in Table 1. IWM treatments had a considerable impact on the production of panicles (m^{-2}). Among the different treatments (Bispyrac sodium+ (Metsulfuron + Chlorimuron) and (Bispyrac sodium + Ethoxysulfuron) both performed equally the good and were at par to each other. The panicle was significantly higher in (Bispyrac sodium+ (Metsulfuron + Chlorimuron) over the remaining treatments. However, treatment (Fenoxaprop-p-ethyl+(Metsulfuron+ Chlorimuron), (Pendimethalin+1 Hand Weeding), (Pendimethalin), (Fenoxaprop-p-ethyl +2,4-D Ethyl ester), (Bispyrac sodium +2,4-D Ethyl ester) followed this. Treatments (control) has significantly minimum panicles.

Number of filled grains per panicle

The observations from each treatment were recorded and data was subjected to statistical analysis. Observing the results as mentioned in Table 1, it can be concluded that the IWM treatments greatly changed the filled grains and panicle. In treatments, (Bispyrac sodium+(Metsulfuron + Chlorimuron) recorded highest number of filled grains recorded and (2 hand weeding) is at par with it, both are significantly higher than the rest of the treatments. However, (Bispyrac sodium +2,4-D Ethyl ester), (Fenoxaprop-p-ethyl +Ethoxysulfuron), and (Fenoxaprop-p-ethyl+ (Metsulfuron Chlorimuron) also followed this, further (Bispyrac sodium + Ethoxysulfuron) and (Pendimethalin+ 1 Hand Weeding), followed same. The lowest grains count was observed from (pendimethslin) and then $^{-1}$ from (control) treatment.

Number of unfilled grains per panicle

Panicles and unfilled grains were counted, and resulted data was subjected to statistical analysis. The mean data of the results are presented in Table 1. It is observed that this parameter significantly influenced due to different treatments. The treatment (2 hand weeding) has significantly lowest unfilled grains, as compared to all the remaining treatments. However, this was followed by (Bispyracsodium + (metsulfuron + chlorimuron), (fenoxapropethyl + Ethoxysulon, (fenoxaprop-p-ethyl + Ethoxysulfuron, (Bispyrac sodium + Ethoxysulfuron) and (Bispyrac sodium +2,4-D Ethyl ester). The other remaining treatments (pendimethalin), (fenoxaprop-p-ethyl + (metsulfuron + chlorimuron), (Fenoxaprop-p-ethyl + Ethoxysulfuron) and (control) recorded the greater number of unfilled grains.

Yield parameters

Test weight (g)

The test weight of 1000-grains were recorded treatment wise and data obtained was subjected to statistical analysis. The results presented in Table 2 reveals that the IWM treatments had significant impact upon this parameter. The treatments (bispyrac sodium+ (metsulfuron+chlorimuron) recorded a higher test weight which was at par with (2 hand weeding). Pendimethalin + 1 Hand weeding recorded the lower test weight which was at par with control plot. These

three herbicidal treatments were discovered to be equally effective and comparable to with that of two-handed weeding. This might be attributed to the higher vegetative growth parameters (plant height and tillers per m^2) in Pendimethalin + 1 Hand weeding, Bisyrac sodium + (Metsulfuron+Chlorimuron) and Fenexoprop– p-ethyl+ (Metsulfuron + chlorimurin) treatments, this indicates that increased, production of photosynthate due to least competition with weeds plant and their translocation from vegetative parts (source) towards the reproductive organs i.e., sink. According to Mahajan and Chauhan (2013), and Chauhan *et al*. (2015), the current results are consistent with those of previous researchers. Several highly promising herbicides and their mixes have been shown to be effective and selective in removing weeds from rice fields by Maity and Mukherjee (2009), Juraimi *et al.,* (2010), Ramachandiran *et al.,* (2012), and Chongtham *et al.,* (2015). The various treatments also had a big impact on the unfilled grains per panicle. The unfilled grains thus dropped naturally as a result of the fact that various weed management methods promoted the quantity of filled grains per panicle. The highly reduced number of unfilled grains per panicle was recorded in case of (2 hand weeding), (Bispyrac sodium + (Metsulfuron + Chlorimuron), (Pendimethalin+ 1 Hand Weeding), (Bispyrac sodium + Ethoxysulfuron) treatments (7.71 to 8.91 per panicle). This was nearly half of the panicle number recorded in case of control treatments. (Singh and Singh, 2010*;* Kumar *et al*., 2015, Singh *et al.,* 2017).

Grain yield (kg/ha)

From the data as shown in table 2, it was observed that the weed control treatments had caused a considerable deviation in the grain yield of direct-seeded rice. The treatments (fenoxaprop-p-ethyl + ethoxysulfuron), (fenoxaprop-p-ethyl+(metsulfuron + chlorimuron), (bispyrac sodium + ethoxysulfuron), (pendimethalin+ 1 hand weeding), (bispyrac sodium + (metsulfuron + chlorimuron) and (2 hand weeding) were found to be at par with each other, respect to the grain production, however this followed by (bispyrac sodium+2,4-D ethyl ester). Treatment (pendimethalin) recorded lower yield which was at par with (fenoxaprop-p-ethyl +2,4-D ethyl ester) treatments. Treatment (control) recorded significantly lowest yield.

Straw yield (kg/ha)

The data as per the straw yield has been represented in the table 2. The parameter has been significantly influenced due to different weed control treatments. The maximum straw yield up was obtained from (2 hand weeding), that closely followed by (bispyrac sodium + (metsulfuron + chlorimuron), (pendimethalin + 1 hand weeding) and (fenoxaprop-p-ethyl ethoxysulfuron) respectively. Further the straw yield was lowered down significantly as successively in treatment (pendimethalin), (fenoxaprop-p-ethyl + 2,4-D ethyl ester), (bispyrac sodium + 2,4-D ethyl ester), (fenoxaprop-p-ethyl + ethoxysulfuron) and (bispyrac sodium + Ethoxysulfuron). Treatment (control) recorded the lowest straw yield. The overall observations shows that (2 hand weeding) was significant superior to all the treatment except (bispyrac sodium + (metsulfuron + chlorimuron).

Harvest index (%)

Due to different weed the harvest index had been found to deviates a little extent, as revealed from table 2. The treatment (pendimethalin+ 1 hand weeding) recorded slightly higher harvest index as compared to all the remaining treatments. However, this was followed by (bispyrac sodium + ethoxysulfuron), (fenoxaprop-p-ethyl+ (metsulfuron chlorimuron), (Fenoxaprop-p-ethyl +Ethoxysulfuron), (2 hand weeding) and (bispyrac sodium + (metsulfuron + chlorimuron) with minor differences in harvest index values. Bispyrac sodium +2,4-D ethyl ester and fenoxaprop-p-ethyl +2,4-D ethyl ester recorded harvest index with slight differences in their values The treatment pendimethalin recorded lower value which is at par with control plot.

Rice farmers are very concerned with productivity parameters such as grain and straw yields per hectare and harvest index since these parameters are ultimately responsible to provide maximum monetary returns per hectare. The relevant as observed shows that all these parameters were significantly influenced due to IWM treatments. Since all weed-flora are uprooted during the hand weeding procedure and the soil is mulched, there is very little possibility that weeds to come back. By doing so, weed competition with the crop plant for nutrients and soil moisture also becomes negligible. In such circumstances, plants produce the maximum amount of photosynthates which ultimately leads to higher yield attributes and hence greater grain yield. Many workers have also noted the advantages of hand weeding over chemical weeding. (Maity and Mukharjee, 2009; Juraimi *et al.,* 2010; Mahajan and Chauhan, 2013; Chauhan *et al.* and Changtham *et al.* 2015). The applied treatments had a direct impact on the grain to straw ratio, which in turn affected the harvest index. The results of the current study are in close agreements with those of numerous researcher*s* (Singh and Singh *et al*. 2010, Kumar *et al*. 2015 and Singh *et al*. 2017).

Economics

Gross income

Among the weed control treatments, application of bispyrac sodium+ (chlorimuron ethyl+ metsulfuron methyl) recorded the highest gross income, almost equally higher gross income was also obtained from Bispyrac sodium + Ethoxysulfuron, and Fenexoprop–p-ethyl+ (Metsulfuron + chlorimurin) having bispyribac sodium with ethoxysulfuron or fenoxaprop-p-ethyl + (chlorimuron ethyl + metsulfuron methyl). The treatments (Fenoxaprop-p-ethyl + (Metsulfuron Chlorimuron) and (Fenoxaprop-p-ethyl + Ethoxysulfuron) recorded equal gross income. Similarly, (Bispyrac sodium +2,4-D Ethyl ester) and (Pendimethalin+ 1 Hand Weeding) recorded the second range of identical gross income.

Net income

The maximum net income per hectare is the ultimate aim of any rice producer. The weed control treatments brought about great variation in giving the net income. Application of bispyribac sodium + (chlorimuron ethyl + metsulfuron methyl) gave the highest net income up to Rs. 48465 per ha. Almost equally higher net income was also obtained from Bispyrac sodium + Ethoxysulfuron, and Fenexoprop–p-ethyl+ (Metsulfuron + chlorimurin) having bispyribac sodium with ethoxysulfuron or fenoxaprop-p-ethyl + (chlorimuron ethyl + metsulfuron methyl) (Rs. 42949 to Rs. 41440 per ha). It is apparent from these data that the application of the dual herbicides as in (Bispyrac sodium +(Metsulfuron + Chlorimuron), (Bispyrac sodium + Ethoxysulfuron) and (Fenoxaprop-p-ethyl+(Metsulfuron Chlorimuron) may be the best substitute of (2 hand weeding). The hand weeding twice has given a higher yield and lower net income Rs.45941 per ha. In case of other treatments, the net income decreased according to the extent of effectiveness of herbicidal treatments to kill the weed-flora and reduce the weed competition with the crop plants. The treatments (Fenoxaprop-p-ethyl + (Metsulfuron Chlorimuron) and (Fenoxaprop-p-ethyl + Ethoxysulfuron) recorded equal net income. Similarly, (Bispyrac sodium + 2,4-D Ethyl ester) and (Pendimethalin + 1 Hand Weeding) recorded the second range of identical net income. Thereafter, the lower net income was obtained from (Pendimethalin) and (Fenoxaprop-p-ethyl + 2,4-D Ethyl ester) treatments. The lowest net income was recorded in case of control plot. This was due to heavy competition of weeds with the crop plants for space, sun-light, essential nutrients and soil moisture resulting in to lower yield and thereby less net income.

Benefit: Cost ratio

Application of bispyribac sodium + (chlorimuron ethyl + metsulfuron methyl) gave the highest benefit: cost ratio. Almost equally higher B:C ratio was also obtained from Bispyrac sodium + Ethoxysulfuron,and Bispyrac sodium + Ethoxysulfuron, having bispyribac sodium with ethoxysulfuron or fenoxaprop-p-ethyl + (chlorimuron ethyl + metsulfuron methyl). The treatments (Fenoxaprop-p-ethyl+ (Metsulfuron Chlorimuron) and (Fenoxaprop-p-ethyl +Ethoxysulfuron) recorded equal B:C ratio. Similarly, (Bispyrac sodium +2,4-D Ethyl ester) and (Pendimethalin+ 1 Hand Weeding) recorded the second range of identical B:C ratio. Thereafter, the B:C was obtained from (Pendimethalin) and (Fenoxaprop-p-ethyl +2,4-D Ethyl ester) treatments. The lowest benefit: cost ratio was recorded in case of control plot. This was due to heavy competition of weeds with the crop plants for space, sunlight, essential nutrients and soil moisture resulting in to lower yield and thereby less benefit cost ratio.

Weed studies

Weed Population and Weed Density

These parameters on weeds were recorded at 30 and 60 DAS stages as revealed from table 3. *Echinochloa sp*. was the monocot weed that was most abundant, with densities of 30.0 and 31.7% at both phases and weed densities of 21 and 32 m^{-2} at both locations. This was followed by *Cynodondactylon,* where this weed was 17 and 26 m^{-2} with density of 24.3 and 25.7% respectively. Among the six types of dicot weeds their population ranged from 2 to 6 m^{-2} at 30 DAS, and 2 to 8 m^{-2} at 60 DAS stage. Accordingly, their density ranged from 2.9 to 8.6% at stage 30 DAS and 2.0 to 6.9% 60 DAS stage.

Total number of weeds (per m^2)

The total weeds including grassy weeds, sedges, and broad-leaved weeds per m^2 before and after herbicide application have been shown in table 3. The total weeds per m^2 were found significantly higher under control either before or after application *i.e.,* 56 and 10 per m^2, respectively. All the herbicidal and hand-weeding treatments (excluding control) resulted in a significant reduction in the total weeds per m^2. In the case of (Bispyrac sodium+(Metsulfuron + Chlorimuron) 27.31 total weeds per m^2 were observed. In case of (Pendimethalin+ 1 Hand Weeding), 32.74 weeds per m^2 only were noted. Similarly, in case of Bispyrac sodium + Ethoxysulfuron, (c) 35.67 weeds per m^2 only were found. Thus, (Bispyrac sodium+ (Metsulfuron + Chlorimuron), (Pendimethalin+ 1 Hand Weeding) and Bispyrac sodium + Ethoxysulfuron

treatments has been proven to be the best substitute of (2 hand weeding) out of total weeds per m^2, 10 weeds per m^2 were still present. The treatments (Bispyrac sodium+(Metsulfuron + Chlorimuron) and (Pendimethalin+ 1 Hand Weeding) were also found better where only 27.31 and 32.74 weeds per m^2 were observed. The treatments (pendimetalin) and (control) were found almost equal in their effect.

Dry weight seeds (per m^2)

The data on weight of total weeds (grassy, sedges and broad-leaved) per metre square before and after pre and post emergence herbicide application have been highlighted in table 3. The dry weight of total weeds per m^2 was found significantly higher in unweeded control after herbicide application *i.e.,* 192.3g per m^2. All the herbicidal and hand weeding treatments (excluding control) brought about significant reduction in the dry weight of total weeds per m^2. In case of (Bispyrac sodium +(Metsulfuron + Chlorimuron), 41.00 g dry weight of weeds per m^2 was noted. In case of (Bispyrac sodium + Ethoxysulfuron) 51.70 g dry weight of weeds per m^2 was recorded. Similarly in case of (Pendimethalin+ 1 Hand Weeding) 49.14 g dry weight of weeds per m^2 was observed. These were the best treatments. In case of treatment (2 Hand weeding twice) only 9.88g dry weight of weeds per m^2 was noted. The other herbicidal treatments (Bispyrac sodium + 2-4 D Ethyl easter, Fenexoprop–p-ethyl + (Metsulfuron + chlorimurin) and Fenexoprop-p-ethyl + Ethoxysulfuron) proved equally effective in comparison to (2 hand weeding) treatment.

Weed control efficiency (%)

The weed control efficiency was worked out treatment wise and the data after statistical analysis have been presented in table 3. The treatment (2 hand weeding) resulted in significantly higher weed control efficiency (WCE) up to 94.85% as compared to (Bispyrac sodium +(Metsulfuron + Chlorimuron) and (Pendimethalin+ 1 Hand Weeding) treatments. The second best treatment was (Bispyrac sodium + (Metsulfuron + Chlorimuron) where the WCE was 78.62 %. The treatments (Pendimethalin + 1 Hand Weeding) proved to be the third best treatment showing slightly lower WCE 74.84%. The significantly lowest WCE (55.70 %) was recorded in case of (pendimethalin). This was closely followed by (Fenoxaprop-p-ethyl +2,4-D Ethyl ester) 60.84 % WCE.

Weed Index (%)

The weed index was worked out treatment wise and the data after statistical analysis have been presented in table 3. The weed index was found significantly lowest in (Bispyrac sodium+(Metsulfuron + Chlorimuron) (12.47%), followed by (pendimethalin + 1 hand weeding) and T_4 (Bispyrac sodium + Ethoxysulfuron) 17.84 to 20.24% and then (Fenoxaprop-p-ethyl+(Metsulfuron Chlorimuron) 21.61%. It was recorded equally higher in (Bispyrac sodium +2,4-D Ethyl ester) 29.39%. The equally highest weed index (39.30 to 56.16%) was noted in (pendimethalin) and (control) treatments.

Conclusion

From the above results it is clear that among the different herbicide combinations, the highest grain yield was obtained under hand weeding and Bispyrac Sodium 25 gm/ha + (Chlorimuron ethyl + Metsulfuron methyl 20 gm/ha (20-25 DAS) and Pendimethalin (30EC) 1.00kg/ha. (3-4 DAS) +1 Hand weeding at 25 DAS treatments. The highest weed control efficiency was obtained under 2 Hand weeding treatment (25 and 45 DAS) 94.85% and Bispyrac sodium 25 gm/ha + (Chlorimuron ethyl + Metsulfuron methyl 20 gm/ha (20-25 DAS) 78.64%, followed by (Pendimethalin 1.00 kg/ha + 1 hand weeding. The higher net income was obtained ≠48465 per ha from (Bispyrac Sodium 25 gm/ha + (Chlorimuron ethyl + Metsulfuron methyl 20 gm/ha (20-25 DAS) and ≠45943 per ha from 2 Hand weeding with respectively B:C ratios of 2.95 and 2.18 respectively.

Table 1: Average mean plant population (per m^2) at 15 DAS stages, Average mean of plant height in (cm) at 30 DAS, 60 DAS, harvest stage, Average mean of tillers (per m^2) at 30, 60 DAS, Average mean of Panicles (per m^2), Number of filled and unfilled grains per panicle.

T No.	Treatments	Plant Population (per m^2)	Plant Height (cm)			Tillers (per m^2)		Panicle (per m^2)	Number of filled grains per panicle	Number of Unfilled grains per panicle
			30 DAS	60 DAS	At Harvest	30 DAS	60 DAS			
1	Pendimethalin	79.63	31	71	98.51	159	282	274.6	95.12	9.5
2	Pendimethalin + 1 Hand weeding	80. 31	30.2	70.4	97.58	162	289	281.6	105.34	8.5
3	Bisyrac sodium +	82.35	29.2	68.5	96.13	169	294	284.3	112.43	8.03

	(Metsulfuron+Chlorimuron)									
4	Bispyrac sodium + Ethoxysulfuron,	82	30.3	70.3	97.66	166	292	282.3	107	8.91
5	Bispyrac sodium + 2-4 D Ethyl easter	82.11	29.5	69.8	96.26	162	286	279.1	110.26	8.96
6	Fenexoprop–p-ethyl+ (Metsulfuron + chlorimurin)	81	29.5	69.3	97.91	161	287	281.7	112.24	9.36
7	Fenexoprop-p-ethyl + Ethoxysulfuron,	82.35	30.3	71.1	98.06	162	287	279.3	111.53	9.2
8	Fenexoprop – p- ethyl + 2 –D Ethyl easter	80.31	29.7	69.4	98.53	160	282	276.3	97.77	8.31
9	2 Hand weeding	83	28.4	68.2	95.94	173	296	289.6	116.66	7.73
10	Control	79.1	31.9	72.9	100.81	98.3	156	149.7	86.91	12.1
	S.Em±	1.04	0.65	0.66	0.71	1.23	1.22	1.1	1.21	0.52
	C.D. (P=0.05)	NS	NS	1.99	2.14	3.66	3.65	3.27	3.61	NS

Table 2 : Average mean of test weight of 1000 grains, Average mean of grain yield and straw yield kg/ha, Average mean of harvest index (%), Average mean of net income and B: C ratio of direct seeded rice.

T. No.	Treatments	Test Weight (g)	Grain Yield (Kg/ha)	Straw Yield (kg/ha)	Harvest Index %	Net income (≠ per ha)	B: C
1	Pendimethalin	23.11	2568	5278	32.77	27936	2.16
2	Pendimethalin+ 1 Hand Weeding	23.05	3480	6424	34.27	37605	2.17
3	Bispyrac sodium + (Metsulfuron+(Chlorimuron)	24.2	3700	6438	34.1	48463	2.92
4	Bispyrac sodium + Ethoxysulfuron,	24.18	3386	6133	34	42951	2.74
5	Bispyrac sodium +2,4-D Ethyl ester	24	2992	5897	33.13	35508	2.44
6	Fenoxaprop-p-ethyl + (Metsulfuron+(Chlorimuron)	24.8	3320	6412	34.07	41447	2.64
7	Fenoxaprop-p-ethyl +Ethoxysulfuron,	23.2	3296	6295	34.17	41396	2.67
8	Fenoxaprop-p-ethyl +2,4-D Ethyl ester	22.5	2722	5358	34.13	29927	2.2
9	2 Hand Weeding	23.03	4236	8163	34.17	45945	2.18
10	Control	22.5	1730	3850	32.67	11799	1.5
	S.Em±	0.33	50.34	97.38	0.38	-	-
	C.D. (P=0.05)	1.02	149.62	289.34	1.15	-	-

Table 3: Average mean of weed population, relative weed density, average mean of Dry weight of weeds (per m^2), weed control efficiency (%), weed index (%) in direct seeded rice in the experimental field.

Treatments	*Echinchloa spp.*	*Commelina spp.*	Other	Total	Dry Weight of Weed per m^2	Weed control efficiency (%)	Weed index (%)
1	15.00 (3.93)	5.31 (2.41)	30.64 (5.58)	56.61 (7.56)	85.68	55.70	39.3
2	8.06 (2.41)	3.00 (1.87)	17.68 (4.26)	32.74 (5.75)	49.14	74.86	17.82
3	5.66 (2.48)	2.68 (1.77)	14.31 (4.67)	27.331 (5.27)	41.00	78.64	12.49
4	7.68 (2.85)	2.64 (1.77)	21.35 (4.67)	35.67 (5.98)	51.70	72.71	20.24
5	8.35 (2.97)	2.68 (1.77)	23.64 (4.91)	37.31 (6.15)	55.85	73.01	29.39
6	7.31 (2.79)	4.00 (2.21)	20.35 (4.56)	36.00 (6.04)	53.60	72.10	21.61
7	8.64 (3.09)	4.00 (2.21)	23.64 (4.91)	39.63 (5.49)	59.50	69.00	22.20
8	11.00 (3.39)	5.31 (2.41)	29.62 (5.49)	51.33 (7.15)	75.27	60.86	35.77
9	1.68 (1.46)	0.68 (1.07)	5.66 (2.48)	10.00 (3.34)	9.88	94.85	0.00
10	21.31 (4.67)	9.64 (3.81)	82.00 (9.08)	125.00 (11.24)	192.35	0.00	56.16
S.Em±	0.46	0.41	0.62	0.73	1.05	0.50	1.21
C.D. (P=0.05)	1.37	1.41	1.87	2.71	3.03	1.50	3.60

Acknowledgement

I express my gratitude to the faculty of agriculture of IANS for their guidance and farm workers for their field support during the research trial.

Competing interests

The authors do not have any competing interests.

Authors contributions

All the authors same contribution in preparing the manuscript. All the authors read and revised the manuscript.

References

Balai, C.M., Bairwa, R.K., Verma, L.N., Roat, B.L. and Jalwania, R. (2013). Economic impact of frontline demonstrations on cerealcrops in tribal belt of Rajasthan, *International Journal of Agricultural Sciences* **3**(7), 566-570.

Bista, B. (2018). Direct Seeded Rice, A New Technology for Enhanced Resource-Use Efficiency. *International Journal of Applied Sciences and Biotechnology* **6**(3), 181-198.

Chauhan, B.S., Awanb, T.H., Abughoc, S.B., Evengelistab, G. and Yadav, S. (2015). Effect of crop establishment methods and weed control treatments on weed management, and rice yield. *Field Crops Research,* **172**, 72–84.

Chauhan, B.S., Mahajan, G., Sardana, V., Timsina, J. and Jat, M.L. (2012). Productivity and sustainability of rice-wheat cropping system in Indo-Gangetic plains of the Indian subcontinent, problems, opportunities and strategies. *Advance in Agronomy*, **117**, 315-69.

Chongtham, S.K., Singh, R.P. and Singh, R.K. (2015). Effect of crop establishment method and weed management practices on weed flora and yield of direct-seeded rice (*Oryza sativa L.). Indian Journal of Agronomy* **61**(1), 33-36.

Juraimi, A.S., Begum, M., Yusuf, M.N.M., Man, A. (2010). Efficacy of herbicides on the control weeds and productivity of direct seeded rice under minimal water conditions. *Plant Protect Quarentin,* **25**(1), 19-25.

Katiyar, P. and Kohle, S.S. (2006). Weed control in direct seeded rice. *Journal of Maharashtra Agriculture Universities,* **31**(3), 284-287.

Khaliq, A., Raiz, M.Y., and Matloob, A. (2011). Bio-economic assessment of chemical and non-chemicle weed management strategies in direct seeded rice. *Journal of Plant Breeding and Crop Science* **3**(12), 302- 3010.

Kumar, V., Roy, D.K., Dharminder, K.R., Kumar, S. and Hans, H. (2015). Influence of crop establishment methods and different weed management practices on growth yield and quality of direct seeded rice (*Orysa sativa* L.). *The Ecoscan.,* **10**(1 &2), 249-252

Mahajan, G. and Chauhan, B. (2013). Herbicide Options for Weed Control in Dry-Seeded Aromatic Rice in India. *Weed Technology,* **27**(4), 682- 689.

Mahajan, G., Chauhan, B.S. and Gill, M.S. (2013). Dry-seeded rice culture in Punjab state of India, lessons learned from farmers. *Field Crops Research,* **144**, 89–99.

Maity, S.K. and Mukherjee, P.K. (2009). Integrated weed management practices in dry direct seeded summer rice (*Oryza sativa* L.) *Indian Journal of Agricultural Science,* **79**(12), 976-979.

Muthayya, S., Sugimoto, J.D., Montgomery, S., Maberly, G.F. (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences* **13** (24),7–14.

Pandey, S., Velasco, L. (2002). Economics of direct seeding in Asia, Patterns of adoption and research priorities. In, S Pandey, M Mortimer, L Wade, TP Tuong, K Lopez, B Hardy (Eds). Direct Seeding, Research Strategies and Opportunities. International Rice Research Institute, Los Banos, Phillipines.

Puniya, R., Pandey, P.C. and Bisht, P.S. (2007). Performance of trisulfuron, trisulfuron + pretilachlor and bensulfuronmethyl in transplanted rice (*Oryza sativa* L.). *Indian Journal Weed Science,* **39**(1&2), 120-22.

Ramachandiran, K., Balasubramanian, R. and Babu, R. (2012). Effect of weed competition and management in direct seeded aerobic rice. *Madras Agricultural Journal.* **99** (4/6), 311-314.

Rao, A.N., Johnson, D.E., Sivaprasad, B., Ladha, J.K. and Mortimer, A.M. (2007). Weed management in direct-seeded rice. Advance in Agronomy **93**, 153–55.

Rao, A.N., Wani, S.P., Ramesha, M. and Ladha, J.K. (2015). Weeds and Weed Management of Rice in Karnataka State, *India Weed Technology,* **29**(1), 1-17.

Singh, A., Nandal, D.P. and Punia, S.S. (2017). Performance of sequential herbicides to control weeds in direct seeded rice. *Journal of Applied Natural Science,* **9**(3), 1324-1328.

Singh, M. and Singh, R.P. (2010). Influence of crop establishment methods and weed management practices on yield and economics of direct seeded rice. *Indian Journal of Agronomy,* **55**(3), 224 – 229.

Tiwari, N., Kolhe, S.S., Mahobia, R.K. and Sahu, T.D. (2006). Effect of herbicides on dry matter accumulation crop growth rate grain yield of direct seeded rice under Chhattisgarh plain. *Journal Interfaced,* **10**(1), 40-43.