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Weed management in the direct seeded rice: A review

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Abstract
Rice is an major crop & staple food in India. In Transplanted rice (TPR) consent standing water necessary. For 1kg rice TPR need 500litre of water but now days water scarcity is there. Better altering option for it is Direct Seeded Rice (DSR). But no method is perfect. In DSR less water required, less labour, same amount of yield as TPR possible but major constraint is weed. Because of rice crop & weed establishment at same time lead to more crop-weed competition. It also because of less water use in DSR comparison to TPR. In several studies show that yield loss because of weed in DSR may be up to from 30 to 90% but as comparison to the TPR it is around 10 to 25%. Control of Weeds timely is very important for good yield specially in DSR. First 30 DAS is really important for controlling weed growth. Delay in controlling weed lead to outburst of weed growth. Controlling method depend on availability of resources. If labour available hand weeding or mechanical method. In the sense chemical method more economically viable & effective. But combination of all method in integrated way will give the better result comparison any other single method in direct seeded rice.

Keywords: Direct seeded rice (DSR), transplanted rice (TPR), weed, herbicide, weed flora, management, weeding

Introduction
Modern day agriculture is a new era of agriculture. In today world Rice and Wheat is most important crop in a sense of production and also income. Specially in India agriculture is emerged in his best from after the green revolution (1965-1967). After the Wheat crop the rice crop is become the major part of the farmer income. Rice is one of the important and staple food of the world people. Rice's scientific *Oryza sativa* & belong to the family Poaceae/Graminae. More than 60% people of the world like the rice. Asia is the favourite place for the rice production and also for the consumption. In Asia around the 90% of the rice is produced & consumed (Nem raj sunda,2019) [72]. Production system basis on the rice provide employment & income to more than 50 million household. In the world after the China in production and consumption India is at 2nd number. But India is 1st in term of area. In case of the productivity USA is at the top, at 2nd Japan and at 3rd position China placed (Nem raj sunda, 2019) [72]. In term of consumption of the total production in the world China consume 1/3rd & India consume 1/5th (Pawar *et al*., 2018) [16]. In India among the cereals rice occupies the 1st position in both area & production.
In case of the both area & production in India West Bengal at top & UP at 2nd place. But in case of the productivity Punjab displaced all and make at the top with 34q/ ha (Nem raj sunda, 2019) [72]. There is famous slogan that is most suited to the India that is "Rice is Life". Because rice is playing an important role in our national food security & it is means way of living a life for millions of households (Pawar *et al*., 2018) [16]. Rice is originated in Indo-Burma region. It has chromosome no. 2n=24 with test weight of 25g. It prefers the acidic soil. It is grown in the wet tropical climate & also in the humid region of the subtropics. It required the temp. of 21-37°c. Rice has greater nutritional value. It has protein content of 6-7% & more amount in brown rice that is 7.9%. It has also fat content present that is amount of 2 to 2.5%. Rice grain is rice lysine that 4% of total amount of protein present. Main protein is "Oryzenin". Rice is water centering & loving crop. In general, it required the 400 to 500 liters of water for the production of the 1 kg of dry matter of the plant. But for the production of the 1 kg of the rice grain it required 5000 liters of water (Nem raj sunda, 2019) [72].
There are several methods of the rice growing i.e. Direct Seeded Rice (DSR), Transplanting, System of Rice Intensification (SRI) & Dapog method etc. But mainly there are two method that are important Direct Seeded Rice (DSR) and Transplanting method. Transplanting method is generally used due to its more production and provide more income. But now days farmer is shifted towards the Direct seeded rice because several issue that are emerged in the past

(Rathika and Ramesh, 2018) [49]. Direct Seeded rice is process of growing rice crop directly by the seed in the field rather than the growing nursery like transplanting method. Or Direct seed rice (DSR) is a rice establishment method which is cost effective in nature and in this dry seed is drilled or broadcast in the non-puddled filed (Yogananda *et al*., 2019) [76, 77]. In transplanting first nursery then puddling after that it required laborer for transplanting & continuous or more amount water required for growing. Now days farmer can't find laborer for transplanting the seedling due to the lockdowns & problems. So, the famer preferred the Direct seeded rice because in this we can sow seed directly with help of machine. Also due to scarcity of water now days due to less rain or depletion of ground water are also reason for the shifting towards DSR (Rathika *et al*., 2020) [50]. DSR benefits it to the farmer by saving irrigation water by 12-35%, labor up to 60% & yield similar or little bit lower than yield of rice (Kumar and Ladha 2011) [31]. For getting better yield in DSR or in any other method it always depends upon the good management of crop.

In comparison of transplanting method direct seeded rice required very less water (vikaspedia.in). In year 2020 Haryana government restricted the growing of rice by transplanting method in several districts of Haryana because of low water level in that districts (tribuneindia.com). Also, Haryana government start giving 7000rs/ acre to the farmer for growing non-paddy crop under the scheme of 'Mera Pani Meri Virasat' (Hindustantimes.com). Direct seeded rice required less water and also the less labor and it mature early (Knowledgebank.irri.org). Direct seeded rice has several benefits over transplanting method that like saving the labor, irrigation water, energy, time and also it reduces the emission of green house because it not required standing water in the field (Kaur and Singh, 2017) [27]. Direct seeded rice can be grown in two ways depend on the land preparation method: Dry direct seeding and other way is wet direct seeding.

Dry direct seeding method is used for rainfed & deep ground water level ecosystem. In dry direct seeding 3 way for sowing: it can be broadcasting, dibbling & drilling (Knowledgebank.irri.org). In general drilling method is used more for direct seeded rice. Wet direct seeding is done in the wet field by method of broadcasting or by drilling the seeds into the mud with a drum seeder (Knowledgebank.irri.org). For the cultivation of the DSR only 34% of the total labour requirement & it save the 29% of the total cost of the transplanted rice (Rathika *et al*., 2020) [51]. There is one drawback of direct seeded rice method that is the weed problem. Management of the Weed in DSR is always remain big issue till time. Yield loss in the DSR is more than the transplanting & other method. According to the Pillai and Rao, 1974 yield loss in transplanting method was 15 to 20%, in low land DSR method was 30 to 35% & in the upland DSR method was more than 50%. Also, acc. to the Singh *et al*., 2005 in Dry seeded rice loose was 75.08%, in wet seeded rice 70.6% & in transplanting method 62.6% under uncontrolled weeds situation. In DSR for good yield it is necessary to keep weed free filed in first 30 days (Pawar *et al*., 2018) [16]. These 30 days make a base for the good yield. In some study it shown that 15 to 60 days are also with concern to the weed in Direct seeded rice. So, management of these weed can be done hand weeding, but it is tedious work. So, use of chemical is a better and effective option. Therefore, use of pre-emergence & early post-emergence herbicide will be quite effective. They will either suppress the weed growth or inhibit the germination of weed seed (Pawar *et al*., 2018) [16].

According to the report of the Reddy (2010) there are some weed that are dominant in the direct seeded rice: in grasses *Echinochloa crus-galli* (L.); under the sedges *Cyperus difformis* (L.), & *Fimbristylis miliacea* (L.) & under the broad leaf category *Eclipta alba* (L.) Hassak & *Ammania baccifera* (L.) are dominant. Acc. to the Riaz *et al*., 2007 report that in DSR *Cyperus rotundus, C. iria, C. difformis, Portulaca oleracea & Eclipta prostrata* are some main weed. Acc. to the Singh *et al*., 2014 report in DSR common weed are: *Echinochloa colona, E. glabrescens, Dactyloctenium aegyptium, Leptochloa chinensis, Cyperus difformis, C. iria, Mazus pumlius, Ammania baccifera, Eclipta alba, Digera arvensis & Fimbristylis miliaceae*.

Weed flora distribution in Direct seeded rice:

In general, transplanted rice is mostly grown all over India. But now days farmer shifted towards Direct Seeded Rice (DSR) because of less water use. When we change our crop there is also change in the Weed flora. Same in case of DSR. When we shift from transplanted rice to Direct seeded rice there is also change or shift in the Weed flora (Singh *et al*., 2008). As compare to the transplanting rice in the DSR weed is more and it get difficult to control many times quoted by the Kumar and Ladha, 2011) [32]. Weed flora in transplanting rice is emerge later and also seedling of rice bigger than weed. But in case of Direct seeded rice it is different. In DSR weed emerge alongside with the crop & it led to the more crop-Weed competition, so management of it is very important (Singh and Singh, 2010).

Weed cause serious problem in the Direct seeded rice. Singh *et al*., 2016 quoted that around 350 species of weed are reported in the rice. From these species grasses cause serious problem followed by sedges than broad leaf weeds causes serious yield loss in crop. According to the Riaz *et al*., 2007 major weed flora in the direct seeded rice were *Cyperus difformis, C. iria, C. rotundus, Eclipta prostrata* & *Portulaca oleracea*. Singh *et al*., 2016 described that *Echinochloa Colona & E. crusgalli* are the most dangerous/ serious weed in the direct seeded rice. Also stated that *E. colona* need less water so it major weed in DSR. Those filed which are poorly managed in that *Cynodon dactylon* & *Cyperous rotundus* are major weed. Other than these major problematic weed in DSR are *Leptochloa chinensis, Paspalum spp., Digitaria sanguinalis, Dactyloctenium aegyptium, Cyperus iria, Commelina spp., Fimbristylis miliacea & C. difformis.* An experimented conducted by the Ganie *et al*., 2014 observed some weed in the field were *Echinochloa Colona, E. glabrescens, Dactyloctenium aegyptium, Leptochloa chinensis, Eclipta alba, Cyperus difformis, C. iria, Ammania baccifera, Fimbristylis miliacea & Digera arvensis.*

According to the Sen *et al*., 2020 major weed flora in unweed situation in direct seeded rice are *Echinochloa crusgalli, Leptochloa chinensis, Digera arvensis, Eclipta alba, Trianthema portulacastrum (*broad leaf weed), *Cyperus iria & C. rotundus* (Sedges). Grassy weeds are present in more percentage & dominant followed by the broad leaf weed & sedges in experimented plot of Sen *et al*., 2020. There are many major weed flora associated with the direct seeded rice that are *Echinochloa colonum* L. (barnyard grass), *Cynodon dactylon* L. (Bermuda grass), *Digitaria sanguinalis* L. (large crab grass) & *Panicum repens* L. (quack grass) among

grasses; in the broad leaf weeds (BLW) major weed are *Digera arvensis* L. (false amaranth), *Physalis minima* L. (native gooseberry), *Ageratum conyzoides* L. (Billy goat weed), *Portulaca oleracea* L. (common purslane), *Commelina Benghalensis* L. (benghal dayflower), *Trianthema portulacastrum* L. (desert horse purslane), *Parthenium hysterophorus* L. (congress grass) and *Abutilon indicum* L. (Indian mallow); and *Cyperus rotundus* L. (purple nut sedge) and *C. iria* L. (rice flat sedge) among sedges were reported by the Yoganada *et al*., 2019. According to the report of Singh *et al*., 2016 in the Direct seeded rice first 30 days broad leaf weeds are more dominant then the grasses and sedges. But after the 30 days in the later stages grasses weed dominant more than the broad leaf weeds and sedges.

Loss due to weeds in DSR

As we know that many experiment & research paper stated that weed in direct seeded rice is in more quantity than transplanted rice. As Singh and Singh, 2010 stated that in DSR weed emerge along with the crop so competition with crop is more. Because of competition weed trying to get more nutrient, water and other valuable resources. So, because of this competition yield loss is also there. How much loss that weed cause that depend upon what kind of management method, cultivar, ecosystem, weed species, time period & critical period for competition (Singh *et al*., 2016). According to Singh 2008 report *Trianthema monogyna* was seem to grow faster & utilize more resource than other weed in the early stage of cycle. In the report of Rao *et al*., 2007 stated that in the world yield loss from pest was 40% from which 32% because of weeds. On average weed loss in rice is 10% and it deteriorate the quality but it can ranges from 30 to 90% and increase the cost of production. Yield loss by *Echinochloa crusgalli* (mainly in grasses), sedges & broad leaf weeds was 41, 10 & 28% respectively (Azmi and Baki 1995) [6]. Transplanted rice has more advantage because 4 to 5 weeks older seedling age than direct seeded rice. Rao *et al*., 2007 estimated that in dry rice yield loss was 50 to 91%. But in the transplanted rice it was 13% (Azmi, 1992) [3]. In case of *Echinochloa colona* density & dry weight is less in transplanted rice than direct seeded rice reported by Dhyani *et al*., 2010 [1].

All around season crop-weed competition cause yield loss up to 80% in direct seed rice stated by Sunil *et al*., 2010.

According to the Pillai and Rao, 1974 yield loss in transplanting method was 15 to 20%, in low land DSR method was 30 to 35% & in the upland DSR method was more than 50%. Also, acc. to the Singh *et al*., 2005 in Dry seeded rice loose was 75.08%, in wet seeded rice 70.6% & in transplanting method 62.6% under uncontrolled weeds situation. Loss of yield because of weed is more in the direct seeded rice rather than in transplanted rice. It mainly because in the difference of rice seedling and weed, also the standing water in the transplanted rice. Weed in the direct seeded can cause loss in yield up to 50% & it is after the one hand weeding in the weeded area (Chauhan, 2012) [10]. Weed is major concern in DSR. Improper management if weed in Direct seeded rice lead severe loss in the yield & less economic returns. According to the Dangol *et al*., 2020 [13] in comparison to weed free plot there was 67.9% loss in weeded plot. Because of weed infestation loss of yield in India is approx. 15 m t in year stated by the Singh *et al*., 2018.

Status of DSR

Direct seeded rice method is getting pace now these days in India. In comparison of Direct seeded rice with transplanted people mainly use the transplanted method for rice. And transplanted much more effective and give better yield but it use lots of amount of the water. Now days water level is going and uneven rainfall also. Because of scarcity of water farmer are shifting towards the Direct Seeded Rice (DSR) & other less use water crops. All three kind of reports come in studies some DSR has less yield, some say even or more yield in DSR than the transplanted rice (Singh *et al*., 2016). In Sarkar *et al*., 2003 study it shows that DSR yield (3.15 t/ha) than transplanted rice yield (2.99 t/ha). Bhushan *et al*., 2007 said that direct seeded rice is grow faster & easier to plant, less labour, short duration & consume less water than Transplanting rice. According to the Wassmann *et al*., 2004 that in DSR less methane emission. During the period of 2014-15 in India Direct seeded rice grown in area of approx. 43.5 m ha with production of 105.5m t & it had productivity of 2.4 t/ha. In specific case of Punjab total area of DSR was 2.89 m ha that had production of 11.11 m t & productivity of 3.8 t/ha within 2014-15 (Kaur and Singh, 2017) [28].

According to an article of The Times of India (2021) in the Punjab area under direct seeded rice has increase to 6.01 lakh ha or close to 20%. But it remain short 10 lakh ha. In an article of The Indian Express (July11,2020) Punjab achieved 20% of its total DSR target area that was 27 lakh ha. It has increase 34% in DSR as comparison from last decade 2010-19. By adopting Direct seeded rice Punjab save the around 30% ground water & also a huge amount of money that was around 600 crores. According to the data collective from the Punjab Agriculture Department that till 6 July in year 2020 5,19,300 lakh ha area had been grown under the direct seeded rice method in the Punjab. But from last decade (2010-19) only 3,87,000 ha was sown under the direct seeded rice. In 2020 this because of Covid-19 pandemic. Due to Covid-19 there is shortage of labour so farmer shifted towards the Direct seeded rice method. It save the ground water & also the lots of money.

Crop-Weed Competition

One of the important thing in today's farming is yield & income from that. But now a days productivity is going down because of the several factor. Rathika *et al*., 2020 [52] described that these factor may be biotic or abiotic. One of the major yield limiting factor is weed. It compete for other essential factor water, light & nutrients etc. Weeds problem is more in the direct seeded rice rather than in transplanted rice. Weed growth much more progressive in direct seeded rice rather than transplanted rice. In DSR weed majorly affected the quality of grain, yield & also increase the cost of production. Yield loss in the direct seeded rice due to weed may be from 10% to complete failure of crop that depend upon weed infestation. Main reason for the decrease in yield in direct seeded rice is competition from weed in the initial stage. But in the later stage decrease in the yield not happen because there maximum damage is already happened (Johnson, 1996) [24].

Damage of the yield in the direct seeded rice is depend upon the several factor like type of weeds, weed infestation, type of variety grow, cultural & management practices for control of

weed. In uncontrolled weeds in the direct wet seeded rice yield can be reduced up to 53% & losses were seen up to 90% reported by the Bhatt and Kukal, 2020 [8]. In the whole season long crop-weed competition in wet seeded rice cause 69.71% reduction in the grain yield reported by the Raj *et al*., 2013. In Muthukrishnan *et al*., 2010 report showed that loss due to weed in DSR low land rice was 45%, in upland DSR 67% & in transplanted rice 34% in India. In the report of Chinnusamy *et al*., 2012 [11] in Tamil Nadu because of weed infestation in rice yield loss was 111.81 thousand tonnes/year. In comparison to other rice growing method direct seeded rice is more sensitive in case of yield loss due to weeds.

Table 1: Method of rice establishment Reduction in yield because of weed

S. No.	Method of rice establishment	Reduction in yield because of weed (%)
1	Wet seeded rice	85
2	Dry Seeded rice	17 to 73
3	Upland rice	97
4	Upland dry seeded rice	94

Loss of yield because of weed infestation in different establishment method of rice (Ladu and Singh, 2006) [33]

Establishment method of rice (TPR V DSR)

As we already know that in modern farming main motive is to earn more & more. So, earning depend upon the yield. More & better quality yield give more earning. Farmer feel more comfortable in growing of transplanting rice rather than the Direct seeded rice. It is because of the better crop establishment in the transplanting rice. In direct seeded rice more weed infestation is there than the transplanting rice. Productivity is important thing in farming. And increase in productivity is achieved by the farmer in the transplanting rice stated by the Singh and Bhattacharyya, 1989 [8]. As Singh and Singh, 2010 stated that in transplanting rice first seedling is prepared and transplanted. So, better crop establishment of rice because weed emerge later and rice seedling is already established. But in direct seeded rice method weed & crop is established at same time. And moisture remain there so as we know weed growth is faster. So they perfoliate more as compare rice in DSR. But in comparison to the transplanted rice, in the TPR method first separate seedling prepare then puddling & after that herbicide & continuous standing water. All these combination provide less weed infestation in TPR then the DSR method. Balasubramanian and Hill, 2002 [7] discuss that DSR has many advantage like in transplanted rice farmer has to use labour for transplanting the rice seedling but in DSR famer can use direct seed drill machine. In DSR less water use for the growing rice but in Transplanting rice continuous stagnation of water is there. In timely sown DSR early 7-10 days earlier maturity, less water requirement and less methane emission. Direct seeded rice is consider one of the best alternate method for transplanting rice method but only constraints in direct seeded rice is heavy weed infestation (Karthika *et al*., 2019) [26].

Shift in Weed Flora

Changing in the way of growing crop or changing the crop will always lead to change in the weed flora. It because of the way the crop is grown. In crop rotation there is different crop its different package & practices, different requirement, different field preparation, crop growth rate, allelopathy & certain different mechanism that suppress weed growth or change their distribution. In different way of growing crop in that different factor are their like different requirement of resources, different practices of growing crop, less or more of nutrient requirement etc. Like in the direct seeded rice less water required than the transplanted rice then the weed which require more water less proliferate. According to the Moody, 1996 there are several factor which effect the distribution of weed in the field: water requirement, landscape, season, soil fertility & herbicide use etc. Because of continuous use of herbicide for grasses there shift in the weed flora i.e. sedges and broad leaf get more dominant in the field. From transplanting to the Direct seeded rice weed control getting easy to difficult. Change in the weed flora is because of change of the sowing time, way of sowing or can say change in the establishment. As Azmi and Baki, 2002 [4] said that lots of use of herbicide lead to resistance of weed & change in the weed flora. According to the report of AICRP-WC 2002-03 in rice for control of grasses butachlor is used that result the change in the weed flora means sedges and broad leaf get dominant. With shift on direct seeded rice there was proliferate growth in the *Echinochloa crusgalli, E. colona (grasses)*; perennial sedges: *Cyperus iria, C. rotundus* & certain broad leaf weed get dominant in the field.

Weed control management

As many studies show that Weed infestation is more in the direct seeded rice because of several factor as comparison to the transplanting rice.as already discussed the in DSR method rice is direct sown in the soil with help of seed drill. So, rice & weed emerge together at same time. Because of emerging at the same competition between rice crop & weed is more. Better growth of crop there better establishment & low competition at the initial stage so crop can proliferate easily. In the initial period of growth crop is much more sensitive to the weed competition or any kind of competition. According to the studies of Ladu & Singh, 2006 [33] that if there is no weed in direct seeded rice for the initial 30 days the yield will be same as the no weed till the harvesting stage. In the studies of Maity and Mukherjee, 2008 [35] controlling weed at initial period means from 0 to 40 days can increase the yield in the direct seeded rice.

Table 2: Rice establishment method Critical period

S. No.	Rice establishment method	Critical period
1	Transplanted rice	0-20 DAT
2	Dry seeded rice	15-60 DAS
3	Wet seeded rice	15-60 DAS
4	Upland Direct seeded rice	30 DAS
5	Rainfed direct seeded rice	0-90 DAS

Critical period in different establishment method of rice (Arunbabu and Jena, 2018) [2].

DAT- Days after transplanting, DAS- Days after sowing

There are several method for weed control management in direct seeded rice. But control of weeds in Direct seeded rice is little bit difficult. So as multiple method for weed control using is better option for control of weeds in DSR. So, integrated weed management is better & desirable way to control the weeds (Rao *et al*., 2007). In several method comes: physical control, Cultural method, Mechanical method, Chemical method & biological control.

Physical control

Hand weeding: Hand weeding is one tedious work to do for weed control management. Because it required more time to do. For hand weeding more no. of labour required, lot of time. But it is best method for control of weeds in any crop. In the weed is uprooted completely. According to the Singh and Namdeo, 2004 that hand weeding at 20 & 40 DAS is best effective major to enhance the crop growth & yield. In the report of Suganthi *et al*., 2005 it show that two hand give the highest panicle no. and grain yield. Payman and Singh, 2008 report showed that hand weed at 30 & 45 DAS give the highest weed control efficiency that was 66%. Also among the all method for control of weeds lowest weed dry weight is recorded in the twice hand weeding (Roy *et al*., 2010). In the experiment conducted by the Sheeja *et al*., 2013 it shows that hand weeding at 20 & 45 DAS shows the higher plant height & more dry among the all treatment in the direct seeded rice. Two hand weeding show the highest test weight among all the treatment reported by the Chaudhary *et al*., 2018 [9]. In the study of Devi and Singh, 2018 [14] it shows that two hand weeding at 20 & 40 DAS get the max. yield, max. dry matter & NPK content in the grain.

Mechanical weeding

After the hand weeding one of the best alternate option is mechanical weeding. In hand weeding lot of labour, lots of time is required. Now days labour is expensive. It cost around Rs300/days. So, mechanical weeder become the option. Mishra and Sahoo, 1971 said that mechanical weeding has several advantage one of them: it had economical advantage, also non-residual (not phytotoxic) & easy to operate. Rotary weeder had the advantage of over 10.9% incr. of yield/ha in comparison of hand weeding was reported by the Senthikumar *et al*., 2003 [57]. During the study of Rajendran *et al*., 2005 it concluded that because of mechanical weeder 22 to 24% yield increase. Juraimi *et al*., 2013 [25] quoted that hand weeding is environment friendly & easy but it is also tedious & labour intensive that is not economical for the famer. In comparison of control mechanical weeding give 72% reduction in the weed density. Mechanical weeding is economic way for small & marginal farmer for control of weed. It practiced in the row seeded rice in between the row with help of hand tool or any power drawn implements (Singh *et al*., 2018). According to the Sarma and Gogoi, 1996 observed during their experiment that in rainfed upland rice a manually operated peg type weeder use & it show great performance with labour saving of 57% as compared to hand weeding which is 127person- days/ha.

Chemical method

Chemical method is better method to control to weed. If we compare to other method like hand weeding is labour intensive, tedious, expensive & time consuming. Chemical method is much effective & economical. According to the Singh *et al*., 1998 that use of herbicide can be consider better alternative for weed control. If weed infestation more in the field it get difficult to manage by hand weeding but it can be easily manage by the use of herbicide. Herbicide can be save the money & labour. In the DSR for controlling the major weed & reduce cost of cultivation herbicide is good option (Jacob *et al*., 2014) [23]. There are several pre-emergence and post emergence available for control of weeds in the direct seeded rice. In the study of Singh *et al*., 2009; Rao and Nagamani, 2007; Gopal *et al*., 2010 reported that in the different pre-emergence herbicide, oxadiargyl 0.10 kg/ha, pyrazosulfron 0.02kg/ha & pendimethalin 1.0 kg/ha.

Pendimethalin one of the major pre-emergence herbicide use for control of grasses. According to the report of Malik *et al*., 2002 [36] that pendimethalin was effective again *Echinochloa spp., Commelina banghalensis* & *Cyperus iria.* But according to the report of Singh *et al*., 2018 concluded from different paper that Pendimethalin control effective more *Echinochloa spp.* as compared to *Cyperus spp.* Singh *et al*., 2012 envaulted that Penoxsulam @20, 22.5 & 25 g/ha have good control the weed density of grasses & broad leaf weeds. Highest grain yield that was 3.43 t/ha was get from pendimethalin 1 kg/ha (pre-emergence), azimsulfuron 0.0225 kg/ha & bispyribac-sodium 0.025 kg/ha post emergence from compared to weedy free 3.5 t/ha. Kaur and Singh, 2015 [29] concluded from their experiment that there are several pre-emergence: pendimethalin 0.75 g/ha, Thiobencarb 1.50kg/ha, Butachlor 1.50kg/ha, Pretilachlor 0.75kg/ha, Pyrazosulfuron-ethyl 0.015kg/ha & Oxadiargyl 0.09kg/ha. Among all them Pendimethalin 0.75kg/ha show lowest weed density for *Echinochloa spp.* at 30 DAS. In the Singh *et al*., 2005 study it concluded that Pendimethalin @2.0kg/ha show the lowest weed population & also for *C. axillaris* combination of bentazone + pendimethalin show effective control.

Porwal, 1999 observed that pre-emergence herbicide is not application every because of unfavourable climate & other factors. Generally farmer use pre-emergence herbicide because grassy weeds more. But due to continuous use of pre-emergence herbicide there is shift of weed flora from grassy to non-grassy weeds reported by the Singh *et al*., 2009. Against the weed *Echinochloa spp., Cyperus spp.* & other weed bispyribac sodium (0.025kg/ha) found to effective in the DSR reported by the Walia *et al*., 2008. According to the Kaur and Singh, 2015 [30] concluded form their experiment that bispyribac sodium @ 0.025 kg/ha post emergence after the several pre-emergence produce lowest weed density then the those pre-emergence herbicide. In the study of Singh *et al*., 2017 [58] at Kaul, Haryana it concluded that *Leptochloa chinensis* can be reduced by the application of fenoxaprop-p-ethyl @0.067 kg/ha with weed control efficiency (WCE) of 92% then the bispyribac sodium @0.025 kg/ha with WCE of 38% in the direct seeded rice. In the experiment conducted by the Mahajan *et al*., 2009 [34] concluded that application of Penoxsulam @0.025kg/ha & bispyribac @0.025kg/ha controlled the weed better in the direct seeded rice with WCE 67% & 85%. Pendimethalin @0.75 kg/ha (pre-emergence) after that bispyribac sodium @0.25 kg/ha (post emergence) application at the 30 days after sowing give WCE 87% & yield 5618 kg/ha. In place of bispyribac sodium if azimsulfuron @.020 kg/ha it give 84% WCE & yield 477 kg/ha reported by Walia *et al*., 2008.

Table 3: Common herbicide used in direct seeded rice in India

Herbicide	Weed species control & Key features	Dosage /ha		Time of application (DAS)	Reference
		a.i. (g,kg)	Formulation (g,kg,ml,L)		
Bispyribac Sodium 10% SC	*Eclipta alba, Fimbristylis miliacea, Ludwigia parviflora, Alternanthera philoxeroides,*	20g	200ml	20	Choudhury *et al*., 2016 [12]
Cyhalofop-butyl 10% SC	*Echinochloa spp.*	75-80g	750-800ml	15-20	Choudhury *et al*., 2016 [12]
Fenoxaprop-p-ethyl 6.7% w/w EC	*Echinochloa spp.*	56.6-60.38g	812.5-875 ml	25-30	Choudhury *et al*., 2016 [12]
Pendimethalin 30% EC	*Echinochloa spp., Fimbristylis miliace, Ammannia baccifera, Ludwigia parviflora, Eclipta alba, Cyperus difformis*	1-1.5kg	3.3-5L	Pre emergence	Choudhury *et al*., 2016 [12]
Oxyflourfen 23.5% EC	*Echinochloa spp., Cyperus iria, Eclipta alba*	150-240g	650-1000ml	Pre emergence	Choudhury *et al*., 2016 [12]
Oxadirgyl	*Cyperus iria, Echinochloa colonum, Ischaemum rugosum*	75-100g		Pre & early post emergence	Agnews, 2021; Singh *et al*., 2016
Penoxsulam	*Echinochloa crusgalli, Cyperus iria*	0.025kg		Pre emergence	Mahajan and Chauhan, 2008 [34]
Penoxsulam + Cyhalofop-butyl	*E. crusgalli C. iria, C. difformis, L. chinensis, & F. miliacea*	12.5g +6.25 g a.i./ ha		6-10	Azmi, 2012 [5]
Benasulfuron methyl	Broad leaf weed and some sedges	300-500g a.i./ha		6-10	Azmi, 2012 [5]
Metasulfuron-methyl + Chlorimuron-ethyl	More effective on broad lead weeds	4g		6-10	Gopinath and Kundu, 2008 [18]
Propanil	Effective against grasses & broad leaf weeds	2-3kg a.i./ha		Post emergence	Agnews, 2021
Pyrazosulfuron ethyl	It broad spectrum control herbicide	15-20g		Pre & early post emergence	Agnews, 2021; Kaur and Singh, 2015
Butachlor	Effective against grasses	1-1.15kg		Pre emergence	Singh *et al*., 2016; Kaur and Singh, 2015
Fenoxaprop-p-ethyl 9.3% EC	*Echinochloa spp.*& some other grasses	60-70g a.i.		25-30	Singh *et al*., 2016

Conclusion

Direct seeded rice has major weed problem. Weed is an major factor which effect the several growth factor & its ultimately affect the yield DSR. First 40 days are critical to get the better growth of the crop. Weed growth in the DSR is pretty much fast. Weed & crop in DSR establishment at same so, weed affect the growth of crop. Controlling of Weed for longer time & to reduce the weeds only one method can't be much effective. So, using all useable method in integrated way to reduce the weed population. Integrated approach can be economical & all effective more than only a single method of weed control. Choose of method integrated weed control should be advisable according to climate, soil factor & availability of resources etc. DSR can be a better alternative for transplanted rice (TPR) because of water scarcity problem now days, labour etc.

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