Different approaches in direct seeded rice system to avert weed infestation: Review

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Abstract:

In direct seeding of rice infestation of weeds is a major problem and it is a big task for the investigators, researchers and rice growing farmers. Different types of strategies, approaches and practices involving the prevention, cultural, manual, mechanical, allelochemical, chemical and biological control have been established and practiced by the growers on a large scale to overwhelmed the difficulty caused by weeds in direct seeding of rice while maintaining the environmental sustainability. To avoid the environmental degradation and deterioration by the application of herbicides (Ethoxysulfuron ethyl, Bispyribac sodium, Butachlor, Orthosulfamuron, Halosulfuron methyl etc.) to control the weeds, strategies in which there is less use of herbicides is done should be developed. Such type of methods which are economical and more profitable to farmers as well eco-friendly must be investigated. Cultivars of rice which have dominant growth over weeds, high seeding rates to insure good crop stand and plant population, use of allelochemicals and biocontrol agents (*Rhynchosporium alismatis, Curvularia tuberculate, Dactylaria higginsii, Exserohilum monoceras*, *Setosphaeria rostrate etc*.) in the form of bioherbicides to control the noxious weed biota like *Dactyloctenium aegyptium, Echinochloa colona, Echinochloa crus-galli, Trianthema portulacastrum, Cyperus rotundus, Scirpus maritimus, Cynodon dactylon* should be studied and used in an integrated approach under direct seeded rice production system.

Key Word:

Direct seeded rice, weed infestation, cultural methods, allelochemicals, chemical, bioherbicides

Introduction:

Rice (Oryza sativa L.) belongs to poaceae family and is savoured by majority of the world's population as staple food. In Pakistan, rice production was 6849 thousand tonnes grown under 2724 thousand hectares during 2016-17. Among cereals rice is the main crop in the world (Ashraf *et al*., 2006), and for the fulfilment of daily nutritional requirement more than half of the human residents of the world depend on rice (Chauhan and Johnson, 2011). For more than hundred million families in Asia and Africa it is a major source of earnings and employment (FAO, 2004a). With the increasing rate of world's population, it is estimated that in next two decades the demand of rice will increase 25% (Maclean *et al*., 2002), and that's why it is a challenge to meet this demand in ecological way with less deterioration of natural resources.

A major conventional method of rice cultivation is transplanting that is done on the puddled soil (compacted to reduce the water infiltration rate of water). Soil physical properties are unsympathetically disturbed by disassembling of soil aggregates caused by excessive and repetitive puddling, at shallow depths of the soil hardpans formed due which it becomes difficult to perform land preparatory operations and for giving proper tilth to the soil lot of energy is required for the upcoming crops in future. A number of factors like shortage of water, high cost of production, less availability of skilled men power and abnormal plant population have limited the production of rice through transplanting method. There has been shortage of skilled labour for transplanting the rice seedlings throughout the period which resulted in less yield of rice due to less number of plants per unit area. To overwhelmed this difficulty and for rescuing the farmers, direct seeded rice (DSR) cultivation system seems only feasible substitute.

Direct Seeded Rice Status:

Under many studies the yields of DSR and conventional transplanted rice systems were found equivalent. For example, (Sarkar et al. 2003) reported higher economic yield in DSR (3.15 t ha^{-1}) than TPR (2.99 t ha^{-1}) due to more panicle number, higher grain weight and less abortive percentage. Along with higher profits, direct seeded rice is easier to plant, crops grow faster and have shorter duration, less requirement of labour, reduced water use (Bhushan *et al.* 2007), conducive to mechanization (Khade *et al.* 1993), reduction in GHG emissions (Wassmann *et al.* 2004) and provide farmers a chance to get more earnings than transplanted rice system (Balasubramanian and Hill 2002). By decreasing the water losses that occur due to evaporation, excessive infiltration, seepage and water needed for land preparation like puddling etc. dry seeding decreases the total water requirement of the crop (Bouman and Tuong 2001). As there is no need of compaction of soil in direct seeding, in rice based cropping system it facilitates sustainability to the next upcoming winter crops (Farooq *et al.* 2008, Singh *et al.* 2005a).

Rice cultivation systems:

Rice cultivation is done in many states under varying environmental conditions. Over past many decades the rice ecological system has been widely diversified by the naturally arising selection force like submergence, drought and biotic stresses (FAO 2004). Commonly for irrigation and effective weed control rice has been cultivated in anaerobic conditions (Bouman 2003). But as a result of water scarcity, less labour reliant and less water utilizing systems were used as substitutes of anaerobic and transplanted rice. Four kinds of rice land ecosystems were characterized by Khush (1997). Worldwide 56.9, 30.9, 9.4 and 2.8% rice area have been estimated in irrigated, rainfed lowland, upland and deep water respectively (FAO 2007). While in Asia irrigated rice growing area is 58.6%, rainfed lowland is 32.1%, upland 6.7% and under deep water cultivation 2.6%. So irrigated rice is the principal production system, among all other in terms of handling and yield attributes. According to report of FAO (2007) more than half of the world rice growing area is inhabited by irrigated rice providing the 75% world's supply. But this most important system is becoming a threat to the global food security due to the shortage of water. After that, crop and resource management techniques such as site-specific nutrient management, combine pest controlling and aerobic rice systems were introduced which intend to enhance profits and decrease the environmental footprint of irrigated rice production (FAO 2014-15).

The practice of establishing the crop in the field form the sown seeds has been referred as direct seeding of rice rather than transplanted seedlings (Farooq *et al.* 2011). There is no need of puddling, transplanting and flooded condition in direct seeding.

Major weeds in DSR:

Prior to the approach of the green revolution and reception of water system, rice was frequently used to be broadcasted into damp soil under rainfed conditions (Pandey and Velasco 2002) and yields were low, inconstant, and exceptionally inclined to weed rivalry, as is as yet experienced today, especially in upland rice (Roder *et al.* 2001). Direct-seeding of rice, in situ of transplant, provides chances for water savings however at the cost of the lack of the restrictive effective of standing water on weed development. So more severe challenges from weeds has to be faced by a crop growing under DSR system, and hence effective weed management is vital for cropping of DSR.

Table No.1 Major weeds found in direct seeded rice system.

Botanical Name	English/ Common Name	Family	Weedy Status
Grassy			
Brachiaria ramose	Signal grass, Sudan Grass	Poaceae	D-category
Commelina benghalensis	Asiatic dayflower	Commelinaceae	DE-minor, Summer annual
Cynodon dactylon	Barmuda Grass, Couch Grass	Poaceae/Graminae	B-major, Summer perennial
Dactyloctenium aegyptium	Egyptian Finger Grass	Poaceae	A-major, Summer annual
Diplachne fusca	Salt meadow grass	Poaceae	D-minor, Summer annual
Echinochloa colona	Swamp Grass, Wild rice	Poaceae	A-major, Summer annual
Echinochloa crus-galli	Barnyard grass, Lock Spur	Poaceae	A-major, Summer annual
Leptochloa chinensis	Sprangletop, Henbit	Poaceae	D-minor, Summer annual
Leptochloa panacea	Asian sprangletop	Poaceae	C-minor, Summer annual
Paspalum paspaloides	Knotgrass	Poaceae	B-major
Schoenoplectus juncoides	Soft rush, Pin rush	Juncaceae	C-minor, Summer annual
Scirpus maritimus/ Scirpus compactus	Bulrush, Earth almond	Cyperaceae	AB-major, Summer perennial
Setaria verticillata	Sandbur, bristly foxtail	Poaceae	C-minor, Summer annual
Sporobolus helvolus		Poaceae	CD-minor, Summer annual
Broad Leaved			
Alternanthera sessilis	Khaki weed, Alternanthra	Amarathaceae	B-major, Summer perennial
Digera arvensis	Digera kondra,	Amarathaceae	C-minor, Annual
Eclipta prostrata	Bitter Weed	Asteraceae	CD-minor, Summer perennial
Marsilea minuta	Water clover, Paper Wort	Marsiliaceae	BC-minor, Summer perennial
Nymphaea nouchali	White water lily	Nymphaeaceae	D-minor, Summer perennial
Sagittaria guyanensis	Arrowhead	Alismataceae	C-minor, Summer annual
Sphenoclea zeylanica	Goose Weed	Sphenocleaceae	C-minor, Summer annual
Trianthema portulacastrum	Horse purslane	Aizoaceae	A-major, Summer annual
Sedges			
Cyperus difformis	Small flower, umbrella plant	Cyperaceae	B-major, Summer annual

Cyperus iria	Flat sedge,	Cyperaceae	B-major, Summer annual
Cyperus rotundus	Purple nut sedge,	Cyperaceae	A-major, Summer perennial
Fimbristylis dichotoma	Hoora grass, Fimbristylis	Cyperaceae	BC-minor, Summer annual

Source: Weed &Weedicides by Muhammad Ashiq and Dr. Zubair Aslam.

Major= Those weed species which are widespread in the crop lands, act as professional robbers and may sometimes lead to complete failure of crops.

A= most important, widespread weeds and inflicting heavy losses as individual species; B= which are well known but as single weed species they cannot inflict so heavy losses

Minor= not widespread, often unable to inflict heavy yield losses

C= less important, lesser intensity; D= potential to behave as professional weeds; E= not reported as weeds before 1980, but today those have attained an important weedy status

In rice production, one of the main biotic constraints is weed infestation. Rice population is infested with numerous forms of weeds colonized by using terrestrial, aquatic and semi-aquatic weeds grown under various agro-climatic conditions, changed cropping structure, tillage and irrigation systems. More than 340 weed species have been accounted for rice, of which grasses are positioned as first posturing difficult issue took after by sedges and wide leaf weeds making significant reduction in rice yield around the world. The prevalent weed related with DSR in Asia has been displayed (Table 1)

Yield losses caused by weeds in DSR:

As an outcome of competition for several growth factors like nutrients, moisture, sunlight, spacing etc. weeds adversely affected the growth and caused greatest yield losses in DSR. Contingent on cultural techniques, rice cultivars, rice biological communities, weed species affiliation, their mass and term of rivalry degree of loss may differ. As linked to other weeds, *Trianthema monogyna* due to its slighter life cycle was found to grow quicker through initial growth stage and contributed much more to the competition (Singh 2008). The rice grain yield losses differ with the sort of rice development, nation or locality where rice is developed as additionally the ecological and social components related with rice agro-biological system (Yaduraju *et al*., 2015; Yaduraju and Rao, 2013). Universally, real yield reductions because of pests have been evaluated ~ 40%, of which weeds caused the most elevated reduction (32%) (Rao *et al.* 2007). A review of tropical Asian rice fields uncovered that in agriculturists' fields uncontrolled weeds were the most noteworthy factor in diminishing yields, causing 23% and 21% lower yields because of weeds becoming above what's more, underneath the rice overhang, separately (Savary *et al*., 2000). Azmi and Baki (1995) evaluated that the yield loss of 41, 28 and 10% caused by grasses (for the most part E. crus-galli), wide leaved weeds and sedges respectively.

Weedy rice (Oryza sativa f. spontanea), otherwise called red rice, has developed as a genuine risk and its infestation is mainly through the usage of unclean rice seeds (Chauhan and Mahajan, 2012; Rao and Chauhan, 2015). Yield losses ranging from 15-100% has been caused by red rice due to its highly competitive ability with the main crop (Farooq *et al.* 2009). If it gets mixed with rice at the time reaping may affect the grain quality (Ottis *et al.* 2005).

In direct seeded rice weeds caused more yield losses as compared to transplanted (Karim *et al.* 2004). In transplanted rice the advantage is that the seedlings are 30-35 day’s old which are more competitive and after the transplanting the emerging weeds are controlled through anaerobic conditions as compared to direct seeded rice system. Weeds cause 50-90% yield losses in rice under dry seeded conditions while the losses are less just 13% in transplanted rice (Azmi 1992). Lowest plant population and dry weight of *E.colona* was recorded in transplanted rice as compared to its direct seeding (Dhyani *et al.* 2010). Sunil *et al.* 2010 reported 80% yield losses caused by lengthy season antagonism of weeds under aerobic rice conditions. In comparison to other rice production systems direct seeded aerobic rice was found highly susceptible to weeds (Anwar *et al.* 2011).

Weed management approaches:

There multiple approaches used for the management of weeds in direct seeded rice. A portion of the methodologies are talked about below and these ought to be utilized as a part of combination as opposed to in separation. Many researchers considered that the application herbicide may be feasible alternative to the manual method of weed control (Chauhan and Johnson 2011). Through adoption of various agronomic principles and practices such as ploughing of soil (Rao *et al.* 2007), fast growing cultivar (Zhao *et al.* 2006a), increasing seed rate (Anwar *et al.* 2011), managing irrigation (Rao *et al.* 2007), managing nutrients application (Blackshaw *et al.* 2005), use of different mulches (Singh *et al.* 2007a) are the options left for cultural control of weeds. Despite the fact that these agronomic practices help to boost aggressive capacity of crop against weeds and in the meantime are eco-friendly and financial, yet may not give worthy level of weed control, particularly in dry soil conditions, where there is high stress of weeds. By using a single management technique weeds can't be controlled as well as it may result in shifting of weeds, developing resistance and it could cause damage to the biodiversity of the ecosystem. So there is need to utilize such type of strategies which not only control the weeds effectively but also not disturb the ecology of the system. Moreover, for managing the weeds farming community has also concerned with those techniques which are less dependent on chemical use (Blackshaw *et al.* 2005). For integrated weed management (IWM), environmentally and economically acceptable practices should be used. Integrated weed management includes the choice, incorporation, and execution of viable weed control implies with due thought of financial matters, natural, and sociological outcomes. Worry over long haul adequacy of herbicide, subordinate management of weeds has strengthened the requirement for IWM. Many researchers reported significant influence of IWM on rice husbandry (Jayadeva *et al.* 2011). To accomplish viable, long haul and powerful weed control in DSR system, one has to incorporate herbicide use with other management techniques.

This review intends to aggregate up prior work on various weed management methodologies in DSR and examine future research requirements and approaches to keep on handling weeds adequately and monetarily in an economical way.

Preventive approaches:

To limit weeds introduction and their spread, preventive methodologies are the most fundamental of all weed control strategies (Buhler, 2002). These approaches include the use of physical and genetically pure seeds, field bunds, structures used for irrigation and farming tools should be free from weed contamination (De Datta and Baltazar, 1996). The accomplishment of avoidance isn't justified unless it is actualized through group activities by implementation of laws and controls. Conversely in current years as a result of accessibility of different operative and cheap control implements like herbicides, avidness has been deemphasized. But it is still used to control the weed biota which is resistant to chemical use and not easily controllable (Buhler, 2002). Weeds have the great capability of changing their growth habit and can easily make adopted them to practices which are being use for their control (Buhler *et al*., 2000). Rice seed debased with the seed of weeds is single of the real reasons for weed pervasion, particularly in direct seeded rice. Mai *et al*. (1998) investigated normal 465 weed seeds/kg rice seeds including 313 weedy rice seeds in Vietnam, which is forty-seven-overlay greater than allowed national virtue limit. It is clear from the small sized grain crops that utilizing certified category of seed might altogether enhance weed management (Cousens and Mortimer, 1995).

Cultural Approaches:

Cultural methodologies assume huge part to decide the aggressiveness of crop by weeds for over the ground and subterranean assets and thus may impact on managing the weeds (Grichar *et al.* 2004). Most these practices can be viewed as methods for weed concealment and an expansion in their productivity would add to greater weed control. In addition, cultural methods are additionally thought to be eco-friendly and when joined with herbicides or different strategies can bring about managing the weeds in a better way.

Stale bed technique and Tillage:

The stale bed strategy is a critical practice that can be utilized beforehand to any crop to diminish the wildflower seed store. In this procedure, afterward pre-sowing water system, fields are leftward in that situation and weeds are permitted to grow and from there on are executed through tilling or with the utilization of non-particular herbicide (e.g., paraquat or glyphosate) use or light tillage. This procedure is very viable in DSR, particularly to control weeds, for example, *cypirus rotundus, red rice*, and outplaced rice seedlings. In the wake of utilizing stale bed system in dry seeded rice the weed populace was 53% decreased when contrasted with where it was not practiced (Singh *et al.* 2009). Because of low seed dormancy of weeds and their inability to emerge from a depth >1 cm, stale seedbed combined with herbicide (paraquat) and zero-till resulted in better weed control (Chauhan and Johnson 2010). To diminish the rate of persistent weeds tillage is an essential cultural technique. Conventional tillage, no till or minimum tillage are the methods which are used to grow direct seeded rice. Through the fluctuations in weed seed scattering in topsoil tillage can disturb weed community. Deep tilling can diminish yearly weed populaces, particularly when planting is postponed to permit weed seeds to rise before conclusive tillage. While light tillage before crop enlargement and post plant tillage after product foundation help to dismiss yearly weeds and hinder the development of lasting weeds. The rice yield was factually at standard if there should arise an occurrence of no till when contrasted and the conventional tillage framework in DSR (Bhattacharayya *et al.* 2006). Another examination recorded that the direct-seeded zero tillage gave at standard yield as contrasted and transplanted (TP) rice (Singh et al. 2008). Another experiment recorded that the direct-seeded ZT gave at standard yield as contrasted and transplanted (TP) rice (Singh *et al.* 2008). A study also revealed that DSR with ordinary seeding (in the readied field) or rotavator seeding was superior to anything zero tillage seeding. Be that as it may, soil quality factors (viz. bulk density, water content, soil organic carbon (SOC) absorption) were essentially better under zero and rotavator tillage than conventional tillage (Bazaya *et al.* 2009).

Brown Manuring:

The practice in which sesbania grown together with rice crop in the same field, later on after 30-35 days of sowing the sesbania crop is killed by using any herbicide is termed as brown manuring. Sesbania plants supress the growth of emerging weeds by not allowing them to get sunlight for their growth in early stages of the rice crop. This practice not only provides essential nitrogen to rice but also protects it from drought stress and nutrient deficiency at early growth stage (CIMMYT 2010, Gurjeet *et al.* 2013). A study (Bhatia *et al.* 2011) suggested that due to brown manuring the decomposition rate organic matter present in the soil increases which caused greater emission of greenhouse gasses.

Irrigation Management:

Irrigation water found to be a dominant discriminating factor for managing weeds in rice crop Water is considered as a best and natural herbicide. Each weed *sp.* require ideal soil dampness level, other than that its development is hindered, and along these lines time, profundity and span of flooding could assume a critical part in stifling weeds. Irrigation depth can be utilized to control numerous weeds however a few species are moderately unaffected by water profundity. An infrequent open door for saving soil moister and bringing down the charge of rice production is offered by great irrigation system management together with chemical control of weeds (Rao *et al.* 2007). The significance of irrigation system for controlling weeds in rice is outstanding yet it's management is yet to accomplish its maximum capacity (Hill *et al.*, 2001). Initial submerging at 4 days after sowing can decrease weed infestation, especially the bulkiness of *barnyardgrass* (Hach, 1999). Efficacy of initially applied post emergence herbicides like pyrazosulfuron-ethyl was boosted however not butachlor and thiobencarb under enhanced irrigation depth (Hach *et al.* 1997).

Nutrition Management:

For decreased infestation and for long term management of weed, management of crop nutrition is favourable methodology (Di Tomaso, 1995, Blackshaw *et al.*, 2004). Nutrient management should be done with such an aim that there is maximum uptake of nutrients form the soil by the crop plant while fewer nutrients are available to weed plants (Di Tomaso, 1995). Since the vast majority of the yearly weeds grow from the upper couple of millimetres of the soil, application of fertilizers on the upper soil would give the weeds measure up opportunity to use nutrients organised with the crop (Melander *et al.*, 2005). Nitrogenous fertilizers have been accounted for to breakdown weed seed torpidity and impact weed densities. A large amount of applied nitrogen is utilized by the weeds which results in less amount of nitrogen available to the crop plants. A few analysts noted that weeds turned out to be less aggressive when application of nitrogen was done at early development phases of crop contrasted and later application, and weeds are observed to be more receptive to included nitrogen than crop (Blackshaw *et al.*, 2000). Be that as it may, survey on management of fertilizer and weed crop relationship has created contradictory conclusion (Blackshaw *et al.*, 2004). It isn't generally perceived that the management of fertilizer can influence crop weed aggressiveness, and results might be weed and crop definite (Blackshaw *et al*., 2004). The competitive stability amid crops plus weeds can certainly modify fertilizer management, however to combine it into integrated weed management approaches are so far to be established (Buhler, 2002).

Cultivar competitive to weed:

For managing weeds rice cultivar tough weed competitiveness is considered a less priced and harmless tool (Gibson and Fischer 2004). There has been broad deviation between the genotypes of rice to compete with weeds (Fischer *et al*., 2001; Zhao *et al*., 2006a, b). The ability of different rice genotypes to suppress the weeds varies up to 75% (Garrity *et al*., 1992). The pervasion of *Echinochloa sp.* was successfully stifled using competitive cultivar of rice and facilitated less dependence on herbicide (Gibson *et al*., 2001). The rice cultivars which have some allelopathic effect can cause destruction to weeds (Olofsdotter, 2001). In some studies, it is detected that owed to better strength and having the trend of initial canopy cover, early maturing rice cultivars and rice hybrids also have a smothering effect on weeds (Mahajan *et al*. 2011). Special bred cultivars of rice are required under direct seeded rice conditions, which have the strength to break the soil layer (formed after rain) mechanically and to assist the seedlings to emerge easily (Zhao *et al*. 2006a), have the root system which is capable to get moisture from the deeper layers of soil under drought and high evapotranspiration rates (Clark *et al*. 2000. Pantuwan *et al*. 2002) and should have the genetic characters which stable the production in different times of planting under DSR.

Seeding Rate:

In direct seeded rice system seeds are used in high rates. To reduce the weed infestation and use of herbicide application, high seeding rate (more plant population) can be practiced as a promising approach (Melander *et al*., 2005; Anwar *et al*., 2011). Farmers use their personal warehoused seed and to compensate losses caused by bad quality of seed, poor crop stand and different pests, they use high seeding rates. The other advantage of using high seeding rates is that it can provide help to supress the growth of weeds. Reduced grain quality and un-uniform maturation of most of the cultivars is observed where the development of weeds is encouraged by less planting density and extraordinary gaps between the plants. It was observed that under high seeding rates of rice the growth of *Leptochloa chinensis* and *Echinochloa cruss-galli* was reduced (Hiraoka *et al*., 1998). Under the conditions of aerobic soils use of more seed rate of rice not only provided weed control but also established a good crop stand (Guyer and Quadranti, 1985). Weed development and yield of crop was improved where the seed rate was 500 seeds/m^2 as compared to less seed rate of 300 seeds/m^2 in case of aerobic soils (Zhao *et al*. 2007). Under conditions of aerobic soil, the growth of weeds was suppressed effectively by 300 seeds/m^2 in direct seeded rice system (Anwar *et al*., 2011). In contrast, less number of productive tillers, more lodging, less use of applied nitrogen and more chance of rat attack is caused by high crop stand, so it must be avoided (Bond *et al*., 2005).

Crop Rotation:

For the management of weeds, rotation of crops is reflected as a dynamic instrument (Liebman and Gallandt, 1997). The most effective method to control the weeds is the rotation of crops which have different growth habits. The regenerative niches of weeds are disrupted by the rotation of crops and it not allowed the weeds to develop adaptation (Buhler, 2002). In crop rotation, a leguminous crop is preferred because it reduces the growth of weeds, shows better nodule activity, delivers balanced nutrient source and improves the organic matter content of soil (Ali *et al*., 2012). Low yield of rice due to more infestation of weeds was detected in Wheat-Fallow-Rice system (Mollah *et al*., 2015). When the rice was rotated with mungbean, the seedlings of weedy rice not survived in mungbean and after that there was no infestation of this in main crop of rice (Watanabe *et al*., 1998). The density of weeds was reduced by rotating the combination of more than 20 crops (Liebman and Ohno, 1998). Addition of forages provides various mechanisms for suppressing the growth of weeds through antagonism, animal grazing and cutting (Gill and Holmes, 1997). Furthermore, addition of a cultivar which is more efficient in using the resources can be helpful for suppressing weeds (Swanton and Weise, 1991).

Intercropping:

Intercropping a common practice in which more than one crop is cultivated on the same piece of land at the same time. Intercropping recorded more yield as compared to monocropping (Barker and Francis, 1986). There is different system of interaction between crop and weeds in intercropping as compared to monoculture (Buhler, 2002). Meanwhile resource availability is important for weed existence, intercropping offers an exceptional chance for managing weeds by better resource use (Buhler, 2002). Solar conduction through the covering is reduced to an excessive degree via intercropping which outcomes in reduction of weed mass and population (Baumann *et al*., 2000). In direct seeding of rice for controlling the weeds, intercropping by sesbania used for 30-35 days was noticed efficient (Singh *et al*., 2007b).

Mulching:

For managing the weed hitches in rice use of mulches is considered as a good approach. To supress growth of weeds, residues of crops can be utilized as mulch in untilled (Chauhan *et al*., 2012) and tilled rice (Bijay-Singh *et al*., 2008). Mulching not only helps to manage the weeds but also it reduces the rate evaporation from surface of soil and also prevents the seeds from the damage of animals and birds (Gaire *et al*., 2013). Use of organic mulches like grasses, stubbles, chaff and dried leaves of sugarcane mechanically inhibits all breeds of weeds to germinate (Gurung, 2006). In rice field where mulch was used, the population of grassy weed plants was less in complete crop growth cycle (Singh *et al*., 2007). Weeds accompanying in DSR were successfully controlled by using the wheat straw as mulch (4t per hectare) and by sesbania intercrop for thirty days (Singh *et al*., 2007a). Soon after direct seeding of rice the use *Eupatorium* mulch or chaff of wheat (5t per hectare) was effective for managing the weeds (Gaire *et al*., 2013). But for management of weeds in direct seeded rice use of mulches may not be enough, as for suppressing weeds by mulching is rainfall dependent, hence for effective management of weeds herbicide application and eradication by hand is required (Adhikari *et al*., 2007). The use of rice straw as a mulch for effective control of weed is a suggested approach.

Manual and Mechanical Control:

Manual control of weeds is the eradication of weeds by hands manually by labour persons, is easy to practice and eco-friendly however tiresome and have required extreme manpower, therefore it is not feasible choice for farmers. To save a rice crop from the infestation of weeds, two hundred persons per day per hectare are required (Roder 2001). Additionally, the similarity between the morphological characters of rice and grasses creates difficulty for manual weeding at initial phases of development. There are many other problems in hand weeding which are faced by farmers, like delayed or cancellation of weeding due to absence of labour or their unaffordable salaries and injury to seedlings of rice. Variable sensitivity is shown by crops to disruption, and dicots are more sensitive than monocots alike cereals (Rasmussen and Accard 1995), so mechanical control of weeds in rice is realistic. In DSR, to control the weeds use of harrows is noticed effective, particularly when the crop plants are bigger in size than plants of weeds to avoid the destruction (Rasmussen and Accard 1995).

Allelopathic Approach:

This approach might prompt less reliance on the utilization of herbicides in direct seeded rice production system. Rice plants through allelopathic impacts on weeds can decrease input costs in light of the fact that the requirement for herbicide application or potentially manual weeding is lessened. In this way, utilizing rice cultivars which have allelopathic assets could profit agriculturists, purchasers and additionally the earth. In rotation of crops or as a component of an intercropping framework, allelopathic plants might give non-herbicide appliance to control weeds. Research centre and field tests have demonstrated that rice allelopathy can stifle both dicot and monocot weeds (Olofsdotter *et al*., 2001). The development of ducksalad (*Heteranthera limosa (Sw.) wild.*) was observed to be reduced through the usage of numerous compliances of rice germplasm in field (Dilday *et al*., 1994), in the southern US ducksalad is a main weed as well as caused a 21% decline in the revenues of DSR. In some of the experiments which were conducted in the field shown that a weed free circle was formed around the singular plants of few cultivars of rice, while some were heavily encircled via ducksalad. The development of lettuce and ducksalad was restricted by the use solution, extracted from the leaves of six-leaved seedling of rice (Ebana *et al*., 2001).

Chemical Control:

In DSR chemical control of weeds through herbicide application is one of the supreme tool for the management of weeds. Soon in view of the non-availability of work at the basic time

Table No. 3: Recommended herbicides for weed control in direct seeded rice system.

Active Ingredient	Chemical group	Herbicide (trade name)	Dose /ha	Application	Targeted Weeds
Ethoxysulfuron ethyl	Sulfonylureas	Sunstar gold 60 WG	50g	POE	*Cyprus rotundus, Scirpus maritimus, Cyprus difformis, Fimbristylis dichotoma*
Bispyribac sodium	Pyrimindnylthiobenzoates	Zebra 10 SC Nominee 20 SC	300ml 200ml	POE	*Echinochloa colona, Echinochloa crus-gali, Scirpus maritimus, Cyprus difformis, Cyprus iria, Alternanthera sessilis*
Butachlor	Chloroacetamide	Machete 60 EC	2000ml	PRE	*Echinochloa crus-gali, Cyprus difformis, Cyprus iria, Leptochloa chinensis*
Oxadiargyl	Oxadiazole	Topstar 80 WP	100g	PRE	*Paspalum paspaloides*
Orthosulfamuron		Kelion 50 WG	200g		*Paspalum paspaloides, Scirpus maritimus, Cyprus difformis, Cyprus iria*
Halosulfuron methyl	Sulfonylurea	Halt/Orcus 80 WDG		POE	*Scirpus maritimus*
Pyrazosulfuron ethyl	Sulfonylurea	Accord 10 WP	250g	POE	*Eclipta prostate, Marsilia minuta, Sphenoclea zeylanica*
Acetochlor	Chloroacetanilide	Acetore 50EC	1250ml	PRE	*Paspalum paspaloides*
Pretilachlor	Chloroacetanilide	Rifit EW 30%	1800 ml	PRE	*Schoenoplectus juncoides, Paspalum paspaloides*
Oxadiazon	Oxadiazoles	Ronstar 25EC	1800ml	Both	Broad spectrum
Chlorimuron-ethyl + Metsulfuronmethyl	Sulfonylurea+	Almix 20WP	20 g	POE	Broad spectrum

of weeding and high work cost, herbicide use in these frameworks is required to increment. Where the morphological resemblance exists among rice and weeds, use of herbicide is too significant particularly in case of broadcasted crop. Because of shortage and extraordinary salaries of labour in enormous area of rice husbandry, weed management based on application of herbicides has become the best and smoothest feasible choice (Anwar *et al*. 2012; Chauhan and Johnson 2011). In direct seeded rice broad and narrow-leaf weeds were controlled effectively by the application of penoxsulum at different doses of 20-25 g/hectare. (Singh *et al*. 2012). Combined application of azimsulfuron and MSMetsulfuron-methyl efficiently controlled the population of *Cyprus rotundus* (Singh *et al*. 2010). *Singh et al*. (2005) reported that pendimethalin application at 2kg ha^{-1} and pendimethalin + bentazone gave lowest plant density of *Echinochloa colona* and *Caesulia axillaris* respectively. Other pre-emergence e.g. oxadiragyl, pyrazosulfuron and post emergence e.g. cyhalopfop-butyl, azimsulfuron, ethoxysulfuron and penoxsulam are the herbicides that controlled the weeds effectively (Rao *et al*. 2007).

It should never be neglected that all herbicides are lethal; they should be taken care of securely to diminish or maintain a strategic distance from exorbitant and expensive squanders, ecological concerns, edit harm, harm to contiguous crops by splash float, damage to the tool, intemperate defilement, build-ups, and damage to valuable life forms. It is prudent to rotate the herbicide blend in every year for deferring the improvement of herbicide resistance in weeds.

Table No.2: Biocontrol Agents used for controlling weeds in Direct seeded rice system.

Biocontrol Agent	Targeted Weed	Reference
Rhynchosporium alismatis	*Alismataceae weeds, Damasonium minus*	Cother *et al.* (2002); Jahromi *et al.* (2001, 2004)
Fusarium sp.	*Alternanthera philoxeroides*	Tan *et al.* (2002).
Curvularia tuberculate	*Cyperus difformis, Cyperus iria, Fimbristylis miliacea*	Luna *et al.* (2002a,b)
Curvularia oryzae	*Cyperus difformis, Fimbristylis miliacea*	Luna *et al.* (2002a,b)
Dactylaria higginsii	*Cyperus esculentus, Cyperus globulosus, Cyperus iria, Cyperus rotundus, Kyllinga brevifolia*	Kadir and Charudattan (2000)
Exserohilum monoceras	*Echinochloa crus-galli, Echinochloa glabrescens*	Huang *et al.* (2001); Chin (2001); Zhang and Watson (1997)
Cochliobolus lunatus	*Echinochloa crus-galli*	Chin (2001)
Drechslera monoceras	*Echinochloa spp.*	Hirase *et al.* (2004, 2004a)
Fusarium pallidoroseum, Myrothecium advena	*Eichhornia crassipes*	Praveena and Naseema (2003)
Plectosporium tabacinum	*Hydrilla verticillata Sagittaria trifolia*	Smither-Kopperl *et al.* (1998); Chung *et al.* (1998)
Setosphaeria rostrate	*Leptochloa chinensis*	Chin et al. (2003); Thi *et al.*

		(1999)
Colletotrichum gleosporiodes Alternanthera alternate	*Sphenoclea zeylanica*	Bayot *et al.* (1994); Mabbayad and Watson (1995); Masangkay *et al.* (1999)

Biological Control:

There are two types of approaches in which the biological control of weeds can be divided into two catagories i.e. 'bioherbicide' and "classical" (Hallett, 2005). The exogenous application of microbes or pathogens can be done in classical approach to control weeds in rice, but yet not executed properly. Therefore, to decrease the use and dependency upon the chemical herbicides, bioherbicides are being tested and used to control the weeds. The use of bioherbicides not only control the weeds, also have no negative effect on the growth of rice and environmental sustainability. Many researchers reported biocontrol agents which are used in the bioherbicides and control multi-type weed species (Table 3). These biohebicides are only commercialized in the developed countries like Australia, Philippines, China etc. However, under tremendous pressure of weeds in the direct seeded rice it is not feasible to use bioherbicides lonely, these should be used in combination with the other weed control methods to increase the effectiveness. There is need to do research in the field of bioherbicides to find out the effective ones against weeds community and make sure their proper preparation, formulation and availability in the market worldwide.

Integrated management of Weeds:

Weed-rice biological connections are never static. The consistent selection of a specific rice genotypes rehearse causes a move in strength and dissemination of rice weeds. In the planning of weed management programs, the kind of rice culture, cultivars developed, tillage, harvesting techniques, planting geometry, manure application and management of irrigation water should be deliberately controlled in order to make ideal conditions for rice development, yet horrible for weed survival. Manual and mechanical weeding in DSR ought to be utilized just in conjunction with other social and compound techniques to limit work necessities where suitable.

None of the individual control measure can give adequate weed control, and along these lines, if different parts are incorporated in an intelligent arrangement, extensive advances in managing can be beneficial. Different agronomic instruments have been assessed for their probability to oversee weeds (Liebman *et al*. 2001). In any case, all the agronomic practices may not work superbly with each product or weed plants (Blackshaw *et al*. 2005). Combination of higher seed rate and well managed fertilizer application in conjunction with constrained herbicide utilize oversaw weeds effectively and kept up exceptional returns (Blackshaw *et al*. 2005). Singh (2008) recorded that the successive utilization of pre-emergent herbicides, for example, pendimethalin, in dry seeded rice and post-emergent use of 2,4-D against sedges and non-verdant weeds in wet and dry-seeded rice might be a superior alternative than the utilization of one herbicide. A portion of the mixes or their successive application may extend the weed control range with better adequacy. Follow up use of 2,4-D and Almix (a prepared blend of chlorimuron-methyl and metsulfuron-methyl) as post-emergent over pre-emergent utilization of pendimethalin in DSR gave successful control of seasonal grasses, wide leaf weeds and yearly sedges.

Conclusion:

There is a great possibility to produce adequate crop yield with direct seeding and it may serve as a good alternative in case of less availability of labour, but only if it is practiced by managing all the principles and practices in an appropriate manner. There is greater infestation of weeds in direct seeded rice and cause dramatic yield losses which results in less earnings from the crop, therefore managing weeds with the use suitable measures is essential. To get long duration efficient control of weeds, various approaches and strategies for example prevention from weeds infestation in the field, appropriate tillage, stale bed, brown manuring through sesbania, growing of competitive rice varieties, using high seed rates for dominant plant population, growing of cover crops, intercropping, using different types of mulches, rotation of different crops, nutrients management, irrigation water management, Allelochemicals, herbicides formulations, use of effective biocontrol agents in bioherbicides and suitable practices of agronomy should be integrated.

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