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Review Article

WEED MANAGEMENT PRACTICES IN AEROBIC RICE – A REVIEW

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Abstract- Rice (*Oryza sativa* L.*)* is the staple food for more than half of the world's population. Over ninety per cent of world rice is produced and consumed in Asia. As a consequence of competition among agricultural, industrial, environmental and domestic users led to scarcity of water and is going to threaten the sustainability of irrigated rice ecosystem. In this context aerobic rice production system plays a vital role in overcoming the problem related to water. Weeds are the greatest constraint in aerobic rice systems, resulting in 62.2 to 91.7 per cent yield losses. The absence of standing water makes aerobic rice more weed infested resulting in competition for resources with crop plants. The studies have revealed that the weed should be controlled with in 20-60 days after sowing to reduce the yield losses. A major chunk of the cost in aerobic rice production is attributed to cost of weeding. In this contrast, usage of herbicides is proven to be more effective but intensive herbicide use can cause environmental contamination and the development of herbicide resistance by weeds. Hence, the sustainability in weed management is achieved by adopting integrated weed management practices.

Key words- Aerobic rice, integrated weed management, herbicides

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Introduction

Among all staple food crops, Rice (Oryza sativa L.) accounts for the dietary energy requirements of almost half of world population. Over 90 % of world rice is produced and consumed in Asia, where it provides 35 – 80 % of total calories uptake. Further, 55% of rice area is irrigated and accounts for 75% of total production, where 90% of the fresh water is used for irrigated agriculture and of which more than 50% is used in rice cultivation. It consumes 3000 to 5000 liters of water to produce 1 kg of rice. In India rice alone consumes 40 % of the irrigation water [1,2]. Rice occupies an area of 43.39 million hectares with an average production of 104.32 million tones with productivity of 2.4 tonnes per hectare in India [3]. Demand for rice is growing every year and it is estimated that in 2010 and 2025 AD, the requirement would be 100 and 400 million tonnes, respectively. India has to increase its productivity by 3 per cent per annum in order to meet the future food requirement [4]. Asia's food security depends largely on irrigated rice fields. But, traditional lowland rice with continuous flooding, in Asia has relatively high water inputs. Water is a looming crisis due to competition among agricultural, industrial, environmental and domestic users. By, 2025 30 % of human population would be threatened by water scarcity because worldwide 70% of water withdrawals is used in irrigated agriculture. Water scarcity is also an important yield constraint in rainfed lowland rice areas which accounts 25 % of rice production. The increasing scarcity of water threatens the sustainability of irrigated rice ecosystem. By 2025 it is expected that 2 million hectares of Asia's irrigated dry season rice and 13 million hectares of its wet season rice will experiences "physical water scarcity " and most of the approximately 22 Million hectares of irrigated dry season rice south and southwest Asia will suffer "Economic water scarcity" [5]. In 2001, IRRI started experimenting on aerobic rice for the Asian tropics to quantify the water savings potential of aerobic cultivation of rice and to evaluate the performances, yield stability and water productivity of continuous aerobic condition."Aerobic rice system involves growing input-responsive, drought tolerant rice varieties in non flooded and non puddle soil using supplementary irrigation and fertilizers to achieve high yields [6]. But major constraint in aerobic rice to get higher yield is weed infestation. Aerobic rice is more prune to weed infestation because of direct seeding practices, dry tillage practices, alternate wetting and drying cycles, wide spacing, and reduced seed rate. All these practices make the condition conducive for germination and growth of highly competitive weeds and cause yield loss of 62.2 to 91.7 per cent [7-11]. Thus the weed management in aerobic rice is critical to enhance production and productivity.

Important Weed flora associated with aerobic rice

Aerobic rice weed community appears as a complex ecological entity. About 51 species have been reported along with aerobic rice of which 34 species were broad leaved weeds (66.7%), 12 species were narrow leaved weeds (23.5%) and 5 species were sedges (9.8%). Among the 75 weed species reviewed, 18 are considered as major weed species such as *Phyllanthus niruri, Aegeratum conyzoides, Celosia argentia L., Mimosa pudica, Protulaca oleraceae L., Aeschynomene indica, Spilanthus acmella* Murray not (L.) L.*, Alternanthera sessilis* L., *Emilia sonchifolia* (L.) DC. ExWight and *Eclipta prostrata* (L.) L. among broad leaved weeds, *Echinochloa colonam* L.*, Dactyloctenium aegyptium* (L.) Willd.*, Panicum repens* L.*, Eleusine indica* (L.) Gaertn.*, Cynodon dactylon* (L.) Pers. *and Digitaria marginata* L. among narrow leaved weeds and *Cyperus rotundus* L.*, Cyperus iria* L. *and Fimbristylis miliaceae* (L.) Vahl., among sedges [10, 12-15].

Critical period for crop weed competition

The critical period has two components: (1) the length of time weed control is required to prevent crop yield losses, and (2) the length of time crops can tolerate weeds before resulting in yield losses. These components combinedly define the critical weed-free period [16]. Thus, knowledge of weed emergence pattern becomes essential for successful implementation of this concept. Several studies on critical period of crop weed competition were conducted and the critical period for crop weed competition in aerobic rice was 20-60 days after sowing [17-19].

Methods of weed control in aerobic rice

Weed management practices in rice depends on the prevalent weeds and weeds that are likely to occur. Any one method may not be effective under all conditions because weeds vary so much in their growth habit and life cycle. Weed control methods can be grouped into direct and indirect methods. Direct methods include physical, chemical and biological methods. Indirect methods include weed prevention, weed eradication and cultural practices.

Indirect Methods

Prevention of weeds

Nature has provided weeds with a number of devices that help them to be disseminated widely. The agencies that facilitate the dispersal of weed seeds far and wide are water, wind and animals, including man. The troubles that weeds create in crops, soil and water are summed up in the adage "one year of seeding is seven years of weeding". To avoid such a situation, a wise step is to follow the principle "prevention is better than cure". Preventive methods consist in sowing crop seeds not contaminated with weed seeds, using manure and irrigation water not laden with them and the enforcement of weed control laws and seed-certification measures [20].

Weed eradication

Eradication of a weed species is an appealing option because it completely removes the detrimental effects of the weed as well as the high cost of continuing control. Eradication is defined as the complete and permanent removal of all wild populations from a defined area by a time-limited campaign. It is important that an eradication campaign is 'time-limited', that is, eradication needs to be achieved by a fixed date otherwise it is really continuing control. Eradication of a newly introduced pest is seen as a favorable option if the pest will: i) increase the cost of production or reduce the volume or value of production, ii) pose health risks, iii) cause extensive environmental damage, iv) lead to quarantines and export restrictions and v) Increase the use of chemicals and other expensive controls. However, controlling an invader at a density sufficiently low that it is tolerable is usually seen as the appropriate response. Often a management plan is specifically aimed at eradication of a species, but the methods are the same as those that would be used to reduce a population to an economically or ecologically acceptable level. Eradication of a species is assumed to be successful when the infestation area has been free from any individuals for the known life of the seed bank. This can be difficult to define as the life of a seed in the seed bank can only be an estimate, and often nothing is known about the seed bank. The main difficulty in eradicating terrestrial plants is that seeds can remain viable in the soil for up to a century. Furthermore, for eradication to be successful the area should be sufficiently isolated so that recolonisation is unlikely to occur [20].

Cultural practices

Cultural practices like competitive varieties, tillage, seed rate, seeding method, spacing and seed priming, water management, Fertilizer management, crop rotation, intercropping and mulching will also plays a vital role in effective weed management in aerobic rice.

Competitive Varieties

Weed competitiveness is defined as the ability of a crop to suppress and tolerate weeds [21]. Cultivar weed suppressive ability is determined by measuring weed biomass in a weedy environment; however, cultivar weed tolerance can only be assessed by comparing grain yields of cultivars with the same yield potential and weed suppressive ability (WSA) in a weedy environment [22]. Though suppressing weeds reduces weed seed production and benefits weed management in the long term, while tolerating weeds only benefits yield in the current growing season, and may result in increased weed pressure from unsuppressed weeds in consecutive seasons. However, strong WSA does not guarantee high yield under weed competition if the yield potential is low. Therefore, the weed competitive genotype should not only suppress or tolerate the weeds but also should improve the yielding ability of the genotype [23]. The aerobic rice genotypes should be short to medium duration varieties with medium to tall plant height, droopy leaves, higher leaf area index and moderate to high tillering ability and highly input responsive [23,8, 24]. Along with the above characters high root biomass and volume correlated positively with competitiveness [25].

Tillage

Tillage influences the weed emergence due to changes in the mechanical characteristics (bulk density, penetration resistance, aggregate mean weight diameter, and surface roughness) of the seedbed [26] as well as the vertical distribution of seeds in soil [27]. By doing primary tillage reduces the annual weed populations by deep placement of weed seeds and also reduces the perennial weed population like *Cyperus rotundus and Cynodon dactylon* by exposing its vegetative propagation materials [28]. Aerobic rice needs secondary tillage for fine seed bed preparation for better germination of rice seeds and helped in reducing the weed infestation [8] and also helped in better proliferation of roots into deeper layers inturn helped in uptake of nutrients and water resulted in better grain yield [29]. Among the weed control practices, these are critical for success, timeliness of weeding is important. Because, weeds offer the greatest competition and cause the most damage at early crop growth. So, early weed control is important and the final choice of any weed control method depends largely on its effectiveness and economics [8].

Seed rate, seeding method, spacing and seed priming

Higher seeding rate is one approach that helps increase crop competitiveness against weeds was reported by [13]. High seeding rates facilitate quick canopy closure, which helps suppress weeds more effectively. At low seeding rates, crop plants take more time to close their canopy, which encourages weed growth [30]. High seeding rates improve the ability of crops to suppress weeds and can reduce yield loss under partially-weedy conditions [31, 24, 32]. Reduced weed density and weed dry weight was observed in row seeding in east west direction [33, 24]. Chauhan and Johnson also reported that providing less row spacing is congenial and effective in controlling weeds as well as getting higher yield [13]. Seed priming (controlled moisture addition technique allowing seeds to be hydrated partially without radicle emergence) reduces emergence time, boosts germination percentage and favours synchronized emergence, this might have a great influence on weed suppression, seedling stand and yield [34]. Seed priming (soaking seeds in Zappa® solution for 24 hrs followed by air drying for 12 hrs) has increased the weed suppressive ability of rice by 22-27 per cent [35].

Water management

The importance of water management in weed control in aerobic rice is well known [36]. Rice emergence and seedling growth is not influenced by drought stress, keeping dry soil surface as long as possible will largely suppress weed emergence and give rice a 'head start' over weeds. However, if a pre-emergence herbicide is applied, an irrigation following sowing is necessary to create a wet soil surface to ensure herbicide efficacy [23]and in southern US many rice producers are using pin-point (PP) irrigation to get rid from red rice (*Oryza sativa*) a major curse in rice cultivation [37].

Fertilizer management

Fertilizer management is the key factor in increasing the vigour of the crop as well as to withstand the competion posed by weeds and may contribute in long term weed management [38]. Fertilizer management should aim at decreasing the nutrient uptake by weeds and vice versa [39]. Reduced uptake of N and attainment of weed biomass was observed due to subsurface band placement of N than broadcasted N [40]. Results have shown that N influenced the germination, emergence and competitiveness of different weeds. In a study, it was reported that total weed biomass increased with increasing N application rate [41]. Application rate should be according to crop requirement and prevailing conditions otherwise leads heavy weed infestation [42]. Furthermore, varying fertilizer application timing may reduce nutrient uptake by weeds as improper time might develop stressful environment to weeds irrespective to crop stand establishment [43].

Crop rotation

Crop rotation is often considered to be a vital tool of weed management [44]. Crop rotation is one of the most important agronomic practices in minimizing the crop associated weeds by reducing weed seed additions to soil weed seed bank [36]. Increasing cropping system diversity has been advocated as a potential means of decreasing the need for intensive chemical inputs for weed control [45]. Inclusion of pulses has reduced the weed infestation in rice [46,47].

Mulching

Weed Density and its dry weight was reduced significantly by application of mulches *viz*., Polythene sheet mulch, sugarcane trash, maize stover rice straw and Biological mulch. However, Mulching with black polythene cover showed good potential for total weeds control in aerobic rice under the sub-tropical soil and climatic conditions [48,49].

Intercropping

Intercropping is a common practice followed both in developing and developed countries. Intercropping suppresses weeds better than sole cropping and thus provides an opportunity to utilize crops themselves as tools of biological weed management. Smother crops like Amaranthus, Indian till was found to be much effective in reducing weed growth (because of its broader leaves and early rapid growth which blocked light from reaching the ground) without affecting productivity of aerobic rice [50, 51]. Intercropping with *Sesbania* for 40 days was found effective in controlling weeds in aerobic rice [48].

DIRECT METHODS

Physical methods

The primary and age old methods of weed control followed most commonly in Asia and African countries are removal of weeds by hand, with weeding tools (hoe, scythe and spade) or with mechanical implements. Although hand weeding is labour intensive, it is still commonly practiced, particularly in areas where labour is abundant and inexpensive [52]. Though these methods are effective and environmental friendly, they require labour input hectare upto 190 man days for two to three weeding operations [53]. Quite often, weeding is delayed or cancelled due to the lack of availability of labour or the expensive labour costs [54]. However the other important problems associated with manual weeding are damage to the rice crop when weeders are moved across the field and mistaken removal of rice seedlings instead of weeds as it is difficult to distinguish between most of the grassy weeds with rice crop at initial stages[55].

Biological methods

Weed control by myco-herbicides are now being studied to reduce herbicide dependency. Allelopathy method**.** Allelopathy, the direct or indirect effect of one particular plant on another through the production of chemical compounds that are released in to the root environment, may provide an alternative weed control strategy. This approach may lead to less dependence on the use of herbicides in rice production. Rice plants with allelopathic effects on weeds can lessen production costs because the need for herbicide application and/or hand weeding is reduced. Dibutyl phthalate (DBP) an allelo compound extracted from culm plus leaves of *Chrysopogon serrulatus* applied at 2.4 kg a.i. ha^{-1} reduced the emergence and shoot fresh weight of *L. chinensis* by >50%, with negligible effect on root and shoot growth of aerobic rice seedlings, suggesting this as the most suitable rate and compound to control *L. chinensis* without injuring rice seedlings [56].

Chemical methods

Employing herbicide for weed control constitute chemical method of weed control. The potential use of herbicides would be the timely weed control or to delay weed growth or to check weed growth during crop growing season and critical period [57]. Chemical weed control in aerobic rice has gained importance because of intensity of weed problem coupled with the lack of labour for weeding and its high cost. Many researchers has worked and still working on weed management in aerobic rice and revealed that herbicide may be considered to be a viable alternative/supplement to hand weeding. Application of pre emergence, post emergence herbicides and its combination *viz.* Penoxsulam @15 g a.i. ha^{-1}, Bensulfuron methyl at 60 g + pretilachlor at 600 g a.i ha^{-1}, Pendimethalin (30EC) @1.00 kg/ha fb Bispyribac sodium (10% SC) @35 g/ha, Pendimethalin 1.0 kg/ha fb Almix 4.0 g/ha and Bispyribac sodium + metamifop 14 % SE at 70 g ha^{-1} + wetter [10, 58-61] has effectively controlled the weed flora associated with aerobic rice and with less reduction in yield. However, controlling the weeds using herbicides is not only our aim along with that public health and environment is also our concern [33] and we also have to think about development of resistance to herbicides by weeds at higher doses as reported by Heap [62], phytotoxicity to crops [63] and reduction of beneficial soil microbial population [64] has renewed the interest to limit the use of herbicides.

Integrated weed management practices

The IWM was first introduced and defined as "the application of many kinds of technology in a mutually supportive manner. It involves the selection, integration, and implementation of effective weed control means with due consideration of economics, environmental, and sociological consequences [65]. Integrated weed management as the choice and application of weed management practices as "many little hammers" which in combination provide crop protection from weed competition and suppress weed communities [36] without effecting the farmers economic and ecological interests. The IWM better utilizes resources and offers a wider range of management options [66]. Integration of diverse technologies is essential for weed management because weed communities are highly responsive to management practices and environmental conditions [67]. A theoretical model of IWM has been suggested by Noda [68]. None of the control measures in single can provide acceptable levels of weed control, and therefore, if various components are integrated in a logical sequence, considerable advances in weed management can be accomplished [69]. Adoption of IWM approach *viz*., Zero till + Stale seedbed with two irrigations + hand weeding, Pyrazosulfuron ethyl at 25 g a.i./ha + hand weeding + intercultivation, Pendimethalin 1 kg/ha+ bispyribac–Na 25 g/ha fb hand weeding and Pendimethalin at 1.0 kg/ha + one hand weeding [11, 70-72] has proven to be the best technologies for controlling the weeds and in getting sustainable yield.

Conclusion: The area under aerobic rice is expected to increase in the future days because of labor and water shortages. Weeds, however, are the major constraints in aerobic rice production. To achieve effective, long-term, and sustainable weed management in aerobic rice, there is a need to integrate different weed management strategies, such as cultural, physical and biological weed management strategies and judiciously using herbicides as last resort rather than as only resort.

Future research needs in aerobic rice

In order to devise a sustainable weed management strategy for aerobic rice,

- Detailed studies need to be done on the biology and ecology of notorious rice weeds.
- Detailed studies on developing competitive transgenic rice varieties are needed.
- In depth study on controlling notorious weeds of aerobic rice through alleopathy is need to be an hour.
- Studies required on soil solarization technique in aerobic rice to control perennial weeds.
- In depth study on biological weed management in aerobic rice is needed.

Application of research: Aerobic rice cultivation is a technology for tail end areas Whereas weeds are the major hurdle in getting the good yield. Therefore in order to overcome this hurdle Integrated Weed Management is the solution with less environmental pollution.

Research Category: Weed management

Abbreviations:
IWM: Integrated Weed Management
IRRI: International Rice Research Institute

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References

[1] Barker R., Dawe D., Tuong T.P., Bhuiyan S.I. and Guerra L.C. (1999) *Proceedings of the 19th session of the International Rice Commission* 7-9 September 1998, Cairo, Egypt. Food and Agriculture Organization, 96-109.
[2] Bouman B.A.M. and Tuong T.P. (2000) *Agricultural Water Management,* 1615,1-20.
[3] Anonymous (2017) Directorate of Economics and Statistics.
[4] Thiyagarajan T.M. and Selvaraju R. (2001) *Proceedings of an international workshop on water saving rice production systems*. Nanjing University, China,15-45.
[5] Tuong T.P. and Bouman B.A.M. (2003) In: Kijne, JW, Barke R, Molden D (eds.), Water productivity in agriculture: Limits and opportunities for improvement. *CABI Publishing*: 53-67.
[6] Bouman B.A.M. (2001) *International Rice Research Notes,* 26(2), 17-22
[7] Sunil C.M., Shekara B.G., Kalyanamurthy K.N. and Shankaralingappa B.C. (2010) *Indian Journal of Weed Science*, 42 (3&4),180-183.
[8] Shashidhar (2010) *Ph.D. Thesis*, University of Agricultural Sciences, GKVK, Bengaluru.
[9] Anwar M.P., Juraimi A.S., Mohamed M.T.M., Uddin M.K., Samedani B., Puteh A. and Man A. (2013) *The Scientific World Journal,* Article ID 916408, 12.
[10] Madhukumar V., Kalyanamurthy K.N., Sanjay M.T., Prashanth R. and Sunil C.M. (2013) *Plant Archives,* 13(2), 771-774.
[11] Sunil C.M., Shankaralingappa B.C., Shruthi M.K. and Shekara B.G. (2015) *Indian Journal of Agronomy,* 60 (4), 541-546.
[12] Kusuma V. (2007) *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, GKVK, Bangalore.
[13] Chauhan B.S. and Jhonson D.E. (2011) *Field Crops Research*, 121,226-231.
[14] Jayadeva H.M., Bhairappanavar S.T., Hugar A.Y., Rangaswamy B.R., Mallikarjun G.B., Malleshappa C. and Channa Naik D. (2011) *Agricultural Science Digest*, 31(1), 58 - 61.
[15] Sunil C.M. and Shankaralingappa B.C. (2014) *Agricultural Sciences*, 5(1), 60-65.
[16] Zimdahl R.L. (2004) 2nd edition, *Blackwell Publishing*, 220.
[17] Singh G., Singh R.R., Singh R.P., Singh B.B. and Nayak R. (1999) *Indian Journal of Agronomy,* 44(4), 722-727.
[18] Azmi M., Juraimi A.S. and Mohammad Najib M.Y. (2007) *Journal of Tropical* Agriculture *and Food Sciences*, 35(2),319-332.
[19] Anwar M.P., Juraimi S., Samedani B., Puteh A. and Man A. (2012) *The* Scientific *World Journal*, http://doi:10.1100/2012/603043.
[20] Walia U.S. (2010) 3rd edition, *Kalyani publishers*, New Delhi: 87-103.
[21] Jannink J.L., Orf J.H., Jordan N.R. and Shaw R.G. (2000) *Crop Science*, 40,1087-1094.
[22] Gibson K.D. and Fischer A.J. (2004) Inderjit (Edition), Weed biology and management. Kluwer, *Academic Publishers*, The Netherlands, 517-537.
[23] Zhao D.L. (2006) *Ph.D. (Agri.) Thesis*, Wageningen University, Netherlands.
[24] Anwar M.P., Juraimi A.S., Puteh A., Selamat A., Man A. and Hakim M.A. (2011) *African Journal of Biotechnology,* 10 (68), 15259-15271.
[25] Mahajan G., Mugalodi S., Ramesha and Chauhan B.S. (2014) *The scientific Journal,* http://dx.doi.org/10.1155/2014/641589.
[26] Carman K. (1996) *Soil and Tillage Research,* 40 (3–4), 204–207.
[27] Chauhan B.S. and Johnson D.E. (2009) *Soil and Tillage Research*, 106,15-21.
[28] Buhler D.D. and Gunsolus (1996) *Weed Science*, 44, 373-379.
[29] Sunil C.M. and Shankaralingappa B.C. (2014) *Asian Journal of Agricultural Research,* 8(2),105-113.
[30] Guillermo D.A., Pedersen P. and Hartzler R.G. (2009) *Weed Technology,* 23, 17–22.
[31] Zhao D.L., Bastiaans L., Atlin G.N. and Spiertz J.H.J. (2007) *Field Crops Research*, 100, 327–340.
[32] Sharif Ahmed, Muhammad Salim and Chauhan B.S. (2014) *Plos One*, 9 (7), 1-10.
[33] Phuong L.T., Denich M., Vlek P.L.G. and Balasubramanian V. (2005) *Journal of Agronomy and Crop Science*, 191, 185-194.
[34] Harris D., Tripathi R.S., Joshi A. (2002) 231-240. In, Pandey S, Mortimer M, Wade L, Tuong TP, Lopes K, Hardy B (Eds.). *Proceedings of the International workshop on Direct Seeding in Asian Rice systems*: Strategic Research Issues and Opportunities, 25-28 January 2000, Bangkok, Thailand. International Rice Research Institute, Los Banos, Philippines, 383
[35] Juraimi A.S., Anwar M.P., Ahmad Selamat, Adam Puteh and Azmi Man (2012) *Pakistan Journal of Weed Science Research*, 18, 257-264.
[36] Rao A.N., Mortimer A.M., Johnson D.E., Sivaprasad B. and Ladha J.K. (2007) *Advances in Agronomy*, 93, 155-257.
[37] Noldin J.A. (2000) *Proceedings of wild and weedy rice in rice ecosystem in Asia- A review* (Baki., B.B., Chin D.V. and Mortimer, M., eds.), 21-24. Loss Banos, IRRI.
[38] Blackshaw R.E., Molnar L.J. and Janzen H.H. (2004) *Weed Science*, 52, 614-622.
[39] DiTomaso J.M. (1995) *Weed Science*, 43, 491-497.
[40] Blackshaw R.E. (2005) *Agronomy Journal*, 97, 1612-1621.
[41] Guza A.E., Renner K.A., Laboski C. and Davis A.S. (2008) *Weed Science*, 56, 714-721.
[42] Major J., Steiner C., Ditommaso A., Falcão N.P. and Lehmann J. (2005) *Weed Biology and Management*, 5(2), 69-76.
[43] Ahmad N.U. and Moody K. (1981) *International Rice Research News,* 6(2),12-13.
[44] Liebman M. and Gallandt E.R. (1997) Jack-son, L.E. Edition. San Diego, CA: *Academic Press:* 291-343.
[45] Liebman M., Mohler C.L. and Staver C.P. (2001) *Cambridge University Press*, Cambridge: 532.
[46] Watanabe H., Vaughan D.A. and Tomaka N. (1998) *International Symposium on Wild and Weedy Rices in Agroecosystems,* 10-11 August 1998, Ho chi Minh City, Vietnam.
[47] Liebman M. and Ohno T. (1998) *Integrated Weed and Soil Management.* Hatfield, J.L., Buhler, D.D and Stewart, B.A. Eds. Chelsea, MI: *Ann Arbor Press:* 181-221.
[48] Mohtisham A., Riaz Ahmad, Zahoor Ahmad and Muhammad Rehan Aslam (2013) *American-Eurasian Journal of Agriculture and Environmental*

Sciences, 13(2), 153-157.

[49] Ehsanullah R.Q., Muhammad Kalim, Abdul Rehman, Zafar Iqbal, Abdul Ghaffar and Ghulam Mustafa (2014) *Journal of Agricultural Research*, 52(3), 395-406.

[50] Umesha Naika (2007) *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, GKVK, Bangalore.

[51] Venkatesha M.M., Krishnamurthy N., Tuppad G.B.and Venkatesh K.T. (2014) *Trends in Biosciences,* 7(18), 2813 – 2817

[52] De Datta SK and Baltazar AM (1996) In: Auld BA, Kim KU (Eds.) *FAO Plant Production and Protection*: 27-52.

[53] Roder W. and Keobulapha B. (1997) *Weed Research*, 37,111-119

[54] Johnson D.E. (1996) *National IPM network. University of Minnesota,* 1-8.

[55] Zhao D.L., Atlin G.N., Bastiaans L. and Spiertz J.H.J. (2006) *Crop Science*, 46, 372-380.

[56] Chuah T.S., Oh H.Y., Habsah M., Norhafizah M.Z. and Ismail B.S. (2013) *Crop and Pasture Science,* 65(5) 461-469.

[57] Ogborn J. (1969) *PANS (C.)* 15, 9-11.

[58] Khawar Jabran, Muhammad Farooq, Mubshar Hussain, Ehsanullah, Muhammad Bismillah Khan, Muhammad Shahid and Dong-Jin Lee (2012) *International Journal of Agriculture and Biology*, 14, 901–907.

[59] Sreedevi B., Sandhyarani A., Srinivas D., Venkatanna B., Vinaykartheek A. and Mahender Kumar R. (2016) *Journal of Rice Research,* 9 (2),28-31.

[60] Singh V.P., Singh, S.P., Dhyani V.C., Banga A., Kumar A., Satyawali K. and Bisht N. (2016) *Indian Journal of Weed Science,* 48(3), 233–246.

[61] Priya R.S., Chinnusamy S., Murali Arthanari P. and Janaki P. (2017) *British Journal of Applied Science & Technology,* 21(5), 1-14.

[62] Heap I.M. (2002) Online Internet, (Accessed on 15 February 2002 and available at *www.weedscience.com*).

[63] Begum M., Juraimi A.S., Omar S.R.S., Rajan A. and Azmi M. (2008) *Agronomy Journal,* 7(3),251-257.

[64] Ayansina A.D.V. and Osa B.A. (2006) *African Journal of Biotechnology,* 5(2), 129-132.

[65] Buchanan G.A. (1976) In *Proceedings of the U.S.-U.S.S.R. Symposium:*.168-184.

[66] Buhler D.D., Liebman M. and Obrycki J.J. (2000) *Weed Science*, 48, 274-280.

[67] Buhler D.D., Hartzler R.G. and Forcella F. (1997) *Weed Science*, 45, 329-336.

[68] Noda K. (1977) Frayer, J.D., Matsunaka S., ed. Tokyo (Japan): *University of Tokyo Press:* 17-46.

[69] Swanton C.J. and Weise S.F. (1991) *Weed Technology,* 5, 657-663.

[70] Virender Kumar, Samar Singh, Rajender S.C., Ram K.M., Daniel C.B. and Ladha J.K. (2013) *Weed Technology*, 27(1),241-254.

[71] Joshi N., Singh V.P., Dhyani V.C., Subhash Chandra and Guru S.K. (2015) Indi*an Journal of Weed Science,* 47(2), 203–205.

[72] Chakraborti M., Duary B. and Datta M. (2017) *International Journal of Current Microbiology and Applied Science,* 6(12), 66-72.