Weed management in upland rice

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ABSTRACT

The problem of weed competition in upland rice is of great economic importance as it may cause 50-91% reduction in grain yield. Upland rice is infested with diverse types of grasses, sedges and broad leaved weeds. Weeds usually appear in several flushes during the growing season of rice in uplands. The initial 7-30 days after rice seeding have been found to be critical with respect to crop weed competition. In upland rice, method of crop establishment and tillage operations have great influence on the nature of weed infestation. Integrated weed management is a viable and practical way to manage weeds in upland rice. Integration of indirect methods viz., crop establishment method, row sowing either manually or using seed drills, selection of suitable cultivars (e.g. Vandana, NDR -97, Virendra, Anjali, NDR-118), placement of nutrients below seeds and water management, and direct methods of weed control like, manual, mechanical and chemicals like thiobencarbs, pendemethalin, oxadiazon, oxadiagryl, oxyfluorfen, cyhalofop butyl, anilophos and nitrofen are the major options of weed management on long term basis in upland rice. Most of the herbicides available in market are mostly suitable for transplanted rice, therefore, new broad spectrum post emergence herbicide molecules which will be able to control various flushes of weeds is a necessity as availability of manual labour is becoming scarce in resource poor upland areas.

Key words: *upland rice, weed management, cultivar, herbicides, tillage*

In South and South east Asia, upland rice is grown in about 4 million ha of level to gently rolling (0-8%) slope land and in 2 million ha where slopes are greater. It is grown at high altitudes up to 2000m and in areas with annual rainfall ranging from 1,000 to 4,500 mm. Soil type range from highly fertile, volcanic and alluvials to highly weathered infertile and acidic types. Only 15% of upland rice grows in the most favourable sub-ecosystem that has fertile soil and a long growing season (Arraudeau, 1995). In India, the total area under uplnd rainfed rice is about 6.1million hectares which accounts for 13.5% of the total area under rice crop in the country(Kar *et al.* 2003). Many upland rice producers grow barely enough to feed their families, although not always the major component of upland farming systems, rice is the dominant and preferred staple food and the focal point of Asian farmer's resource allocation decisions. Upland rice is typically a subsistence crop and farmer's apply few or no purchased inputs and do most of the work by hand, though animals are used for tillage.

Upland rice is grown as rainfed in moist humid subtropical climate and naturally well-drained soils. Strictly defined, upland rice fields are not bunded and no surface water accumulates. The upland rice ecosystem is extremely diverse, ranging from shifting cultivation to relatively intensive systems, utilizing hand, animal or mechanical tillage and rotations with other crops, including cotton, legumes and other cereals. Upland rice is also raised under shifting cultivation. Shifting cultivation occurs throughout the humid forest zone, where land is cleared from forest usually by slash and burn and rice is grown for one or more seasons before the land is returned to fallow. Invasion of weeds is the principal reason for abandoning.

Weeds rank second to moisture stress in reducing upland rice grain yield and quality (Sankaran and De Dutta, 1985). Aerobic soil conditions and dry tillage practices in upland rice, besides alternate wetting and drying make the conditions conducive for germination and growth of highly competitive grasses, sedges followed by certain broad leaved weed species which cause a grain yield loss of 50-91% (Moorthy and Manna, 1993; Paradkar *et al*.1997).

Reasons for losses due to weeds in upland rice

Crop production in upland rice depends highly on the storage and utilization of soil moisture. Upland aerobic rice experiences moisture stress during its growth due to break in the monsoon which may occur in any month and at any stage of crop growth. Under moisture stress condition, infestation of weed flora intensifies the competition for soil moisture. Several weed species transpire at a greater rate than the crop plants (Rao, 2011). Weeds deprive the crop of 20-40% of the soil moisture. They emerge in several flushes coinciding with seedling, tillering and reproductive stages of direct seeded upland rice. Transplanted seedlings have a competitive advantage over newly emerged weeds compared with emerging rice seedlings in upland rice. Early weeds in transplanted rice are controlled by flooding, which is not the case in upland rice. C_3 plants are dominant in submerged soils whereas C_4 plants are dominant in rainfed soils. Upland rice is heavily infested with C_4 weeds most of which are more competitive in upland conditions.(Ampong-Nyarko and De Dutta,1989). The currently registered herbicides in India have been developed for transplanted rice and are less effective in upland rice.

Crop weed competition in upland rice

Early emergence of weeds relative to rice seedlings and their rapid growth result in severe crop weed competition for light, nutrients, moisture and space in upland rice. Weeds cause most injury to the crop during certain crop growth stages i.e. critical period of crop weed competition. Knowledge of critical period will enable farmers to make most efficient use of their limited labour resources resulting in time and cost saving weed control practices. Ladu and Singh (2006) reported that initial weeks are most critical period for weed control in upland rice. The crop is very sensitive to weeds during tillering stage to just before heading stage. (Singh *et al*. 1989).

The variability of weed species in upland rice tends to be greater than the other production systems and is dependent upon the cropping system and management practice (Table-1). Among the families, Poaceae encompasses nearly 28% of all weed species found in upland rice Cyperaceae and Asteraceae each represent 10%; Amranthaceae, Euphorbiaceae, and Papilionaceae represent 5% each and Commelinaceae, Malvaceae, Rubiaceae, and Convulvulaceae each represent 3% of the total weed species present. (Sankaran and De Dutta,1985). *Cyperus rotundus* is one of the most noxious weed in upland rice, however, its density vary in different upland rice growing areas (Holm and Herberger, 1969). It is also a problem because it germinates and grows with upland rice (De Datta, 1974a). *Echinocloa colona* is the second most serious weed in upland rice, possibly because it needs less soil moisture for growth than *Echinochloa crus-galli* (Noda,1977).

Economics of weed management

One of the earlier researches carried out at dry land research centers of India, exciting examples of the benefit of weed control were observed (Friesen and Korwar, 1983). The percent increase in yields of upland rice in various dry land centers varied greatly from 59-374% (Table-2). This would result in enormous economy to the farmer. Porwal (1999) also reported that pre-emergence application of oxyfluorfen @ 1.0 kg ha^{-1} gave maximum B:C ratio of 6.32:1 in direct drilled upland rice under agroclimatic condition of Banswara, Rajasthan.

Primary weed control method like herbicide, hand hoeing and weeding, increase rice yield by reducing weed density. Secondary weed control methods, such as seed bed preparation, moisture conservation, and crop rotation, directly reduce weed pressure and increase rice yields. Other secondary weed control methods, such as seeding method and density, increase the competitive ability of rice. (O'Brien, 1981).

Integrated weed management

Integrated weed management (IWM) is generally accepted to be the farmer's best combination of cultural, biological and chemical measures that yield the most cost effective, environmentally sound, and socially acceptable weed management for crops in a given situation (Smith and Reynolds, 1966). Farmer's field activities directly or indirectly influence weed growth in almost every phase during the vegetative period. Crop husbandry, plant nutrition, crop protection and farm hygiene are the major factors, which in one way or another have been demonstrated to affect

Table 1. Major upland rice weed species in India, their life form and photosynthetic path way (Mishra, 2003).

Species	Common name	Life cycle	Photosynthetic pathway
Aeschynomene americana L.	Vetch	A Board leaved	C_3
Ageratum conyzoides L.	Goat weed	Ephemeral Broad	C_4
Commelina nudiflora L.	Day flower	A Broad leaved	NA
Cynodon dactylon (L) Pers	Bermuda grass	P Grass	C_4
Cyperus cuspidatus Kunth		A Sedge	C_4
Cyperus difformis L.	Umbrella sedge	A Sedge	C_3
Cyperus rotundus L	Purple nut sedge	P Sedge	C_4
Celosea argentea L.	Cock's comb, Crow's foot	A Broad leaved	NA
Dacteloctenium aegyptium (L) Willd	Crow's foot	A Grass	C_4
Digitaria ciliaris (Retz) Koel	Crab grass, Finger grass	AGrass	C_4
Echinochioa colona (L) Link	Jungle rice, Awn less barnyard grass	A Grass	C_4
Euphorbia spp	Garden supurge/ Pillpod supurge	A Borad Leaved	C_4
Imperata cylindrica (L.) Raeuschel	Cogon grass	P Grass	C_4
Paspalum orbicuiare Forst		A Grass	C_4
Panicum repens (L.)		A Grass	C_4
Saccharum officinarum (L.)	Tiger grass	P Grass	C_4
Setaria glauca (L) Beauv	Fox lall,	A Grass	C_4

A - Annual, P - Perennial (uniform gap)

germination and development of weeds as well as weed population dynamics. Integrated Weed Management emphasizes the use of different techniques to anticipate and manage weed problems rather than react to them after they are present. Therefore, IWM aims at preventing seed production, reducing weed emergence and minimizing weed crop competition, not predominantly complete weed control. An important objective is the integration of different weed management tactics into a long term strategy, which supports sustainable crop production.

Table 2. Benefits from weed control in upland rice at various dryland centers in India,1971-81 (Friesen and Korwar, 1983)

Dryland centre	Crop yield (tonne ha^{-1})		
	Traditional weed control methods	Improved weed control methods	Increase in grain yield (%)
Dehradun	0.71	3.37	374
Varanasi	1.70	2.70	59
Rewa	1.66	2.70	63

Each example represents an average of at least 3 year's data from non-replicated demonstration plots on farmer's field

Results indicated that integrated approach of weed management i.e. deep tillage associated with herbicide and mechanical control enhanced the carry over soil moisture after the harvest of rice (Singh *et. al.*1993). It was also observed that preparatory tillage (either deep or shallow) produced least competition due to weeds when combined with post seeding weed control measure of pre-emergence herbicide and mechanical control were applied. Furthermore, at all levels of tillage, application of pre-emergence herbicide was found effective in controlling weeds than inter-culture. Inter-culture at later stage (one month after sowing) may further become effective in control of weeds. However, during severe drought conditions weed should not be removed from the field and mechanical weeding should also be avoided as there is rapid depletion of soil moisture due to removal of weeds or inter-culture operation (Mishra, 2003).Under IWM various practices may be combined together depending on conditions and availability of resources.

Summer ploughing

Tillage during summer months bring some weed seeds from sub surface to surface which are decayed due to heating. Some weed seeds from surface are placed in deeper layer of soil which prevents their emergence. The nuts (rhizomes), tubers of perennial weeds are cut into pieces and are exposed to sun resulting in their desiccation. This advantage is missed when field preparation is started after onset of monsoon. Disking immediately prior to planting destroys existing weeds and allows the rice crop to be competitive with later emerging weeds. Tillage practices are soil and site specific and for each agroecological conditions optimum tillage methods should be evolved for their particular soil and weed problems.

At Varanasi, many pre-monsoon tillage practices were compared that had little advantage over traditional ploughing at the onset of monsoon, either from standpoint of weed control or grain yield. (Friesen and Korwar, 1983)

Method of crop establishment

Direct seeding is the only method of rice establishment in uplands. Broadcasting, dibbling and drilling are the common seeding practices for upland rice**.** The crop should be sown preferably in rows either by dibbling or drilling instead of broadcasting to facilitate interculture and other operations (Longchar *et al.* 2002).In row sowing fertilizer can be placed below the seeds for better availability to the crop.

Dry seed is sown at the beginning of the rainy season after either minimum zero tillage in the shifting cultivation systems (Singh, 1988). In more intensive systems hand broadcasting or dibbling seeds into furrows or drill seeding in rows by machine is used for seeding at shallow depths into moist aerobic soil (Hill *et al*. 1991). The use of only high quality certified seed is prerequisite for solid and uniform stand of rice. A maximum of 0.05% weed seed is allowed in certified rice seed. There is zero tolerance for objectionable or noxious weed seeds.

Timely sowing and rapid canopy closure minimize weed growth and ensure good crop stand establishment. The sowing time of upland rice is site specific and depends on agroclimatic conditions. Earlier sowing of drilled rice in heavy rainfall areas decreased the grain yield (Lakpale *et al.* 1994). The crop sown 20 days after onset of rainfall recorded significantly higher yield under agro-ecological conditions of Dapoli, Maharashtra (Mane and Raskar, 2002).

Suitable cultivar for upland rice

Upland rice cultivars with drought avoidance (through deep root systems) and drought recovery abilities are preferred. Upland rice in India is grown during the wet season (June-Sept.). In Varanasi region of Uttar Pradesh, where rainfall is more than 750 mm annually double cropping is more common. Water availability period in the region is 234 days (from 26th to 5th standard week). Under such conditions, raising wet season rice of suitable variety (almost 100 days duration *viz*., Vandana, NDR-97, Virendra, Anjali, NDR-118) and conserving soil moisture for succeeding dry season crop will be imperative (Singh *et al*. 2008). Selecting a suitable variety which matches the rainfall duration and competitive to weeds will be a major non monetary input in upland rice cultivation.

Many rice farmers plant local rice varieties that does not respond well to improved management practices. But these cultivars are well adapted to the variable constraints in the ecosystem and have grain quality characteristics that meet the specific local needs. The Central Rice Research Institute (CRRI), India has so far developed 12 high yielding rice varieties for rainfed upland ecosystem. Extra early varieties like Heera, Dhala Heera and Sneha maturing 68-75 days were found suitable for low rainfall drought prone areas, while early varieties namely Kalinga-III, Vanaprbha, Neela, Vandana, Anjali, Hazari Dhan and Annada maturing 85-105 days have become already popular in high rainfall uplands.

Weed competitive rice cultivars

Intermediate-stature cultivars with moderate tillering, large panicles, blast resistance, and tolerance for iron deficiency and aluminum toxicity are also desirable. Cultivars for sustainable systems should be both high yielding and competitive against weeds. Enhancing rice competitiveness against weeds would provide a low-cost and safe tool for integrated weed management to reduce herbicide dependence. Two factors contribute to crop competitiveness with weeds: weed tolerance (WT), the ability to maintain high yields despite the presence of weeds and weed suppressing ability (WSA), the ability of the crop to reduce weed growth through competition (Goldberg and Landa,1991; Jannik *et al*. 2000). Differences in weed suppression ability among upland rice cultivars have been reported by Garrity *et al.*(1992). Tall varieties of rice smother weed growth due to long and droopy leaves and initial faster growth in comparison to weeds (Jennings and Aquino,1968 ; Garrity *et al*. 1992). Garrity *et al*. (1992) found that the height of upland rice was strongly correlated with weed suppression, but other traits such as crop dry matter and leaf area were also associated with competitive ability.

Allelopathic rice cultivars

Varietal differences of rice in allelopathy and weed suppression ability has been reported by Olofsdotter *et al*. (2001). Laboratory and field experiments have shown that rice allelopathy can suppress both monocot and dicot weeds. (Olofsdotter *et al*. 1995; Kim and Shin, 1998; Hassan *et al*. 1998; Dilday *et al*. 1991). Dilday *et al*. (1994) found several accessions of rice germplasm in the field to decrease the growth of ducksalad (*Heteranthera limosa* (Sw.) Wild.), which is a major weed in the Southern United States and causes 21% reduction in the yield of direct-seeded rice (Smith *et al*.,1988). In field experiments, some rice cultivars produced a weed free radius of 10 to 15 cm around an individual plant while others were densely surrounded by ducksalad. Rice cultivars with an allelopathic effect to barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.) have been screened in the field and laboratory conditions (Olofsdotter *et al*.1995). Ebana *et al.,* (2001) studied the allelopathic effect of rice on lettuce (*Lactuca sativa* L.) and ducksalad with water-soluble extracts. Extracts from the leaves of rice seedlings at the six-leaf stage inhibited the growth of ducksalad and lettuce, and a close relationship existed between the inhibitory effect and the two test plants. Chou (1998) had reported six phenolic acids (p-salicyclic, p-coumaric, vannilic, syringic, ferulic, and mandelic acid) associated with allelopathic properties. Sixteen potential allelo-chemicals, including the above mentioned compounds have been found in rice.(Olofsdotter *et al*.1995). Leaf and root extract of cultivar like Dongjinbyeo, K-21, Kouketsumochi at different concentrations have been found to be inhibitory on shoot and root growth of barnyard grass(Kim and Shin, 2005). The drudgery and cost of weeding will be reduced if genes for allelopathic effects can be incorporated into rice.

Herbicide resistant rice

Herbicide resistance rice varieties are a new tool for managing weeds in rice production system. These varieties would enable early season weed control in upland rice. Another advantage of HR-rice, especially glyphosate or glufosinate-resistant rice, is that both are used post emergence and will promote total post-emergence weed control. HR-rice would enable application flexibility due to the high efficacy of these herbicides and good crop tolerance (Olofsdotter *et al*. 2000).Two varieties of herbicide tolerant rice (Liberty link and Round raedy cultivars that withstands the application of the nonselective herbicide glufosinate and glyphosate, respectively) have been developed (Thien *et al.* 2005). However, benefits of herbicide resistance rice must be weighed against potential risks before widespread adoption is encouraged.

Nutrient management

The extent of nutrient competition differs with the time and method of fertilizer application, even if same quantity is applied at different times. Broadcasting method of fertilizer application has been found to enhance weed growth and its competitive ability. Fertilizers placed as narrow soil bands, rather than surface broadcast, has been found to reduce the competitive ability of weeds. Further, it has been also found to reduce fertilizer application rates, if it is used as deep or surface banding of nutrients in the crop row. Fertilizer application should be timed to prevent weed proliferation and maximize benefit to the crop. Where effective weed control is impossible nitrogen application should be delayed until weed nitrogen uptake has slowed so that more will be taken up by the competing rice crop (Matsunaka,1970).Proper weed control is mandatory when fertilizer is applied to crop. Nitrogenous fertilizer is applied in split doses to increase the vigor and competitive ability of crops against weed. Before top dressing of nitrogenous fertilizer, weeds should be managed effectively. Increase in grain yield due to nitrogen application up to 80 kg ha^{-1} in upland direct seeded rice has also been reported by Roy and Mishra (1999). The fertilization should be done as per the requirement of the crop and soil conditions, sub-optimal doses of fertilizer reduce the competitive ability of the rice crop. Under the acidic upland soils, application of rock phosphate at the time of sowing has been found to be better in comparison to single super phosphate in reducing weed growth (Mishra, 2003).

Manual and mechanical methods

Manual method of weed control is successful under conditions where labourers are easily available.

Two manual weeding before 40 days after rice seeding has been found to be satisfactory in reducing crop weed competition (Angiras and Sharma, 1998; Chaubey *et al*. 2001; Moorthy and Saha, 2002). The second weeding should be done in accordance with the split doses of nitrogen application schedule. Mechanical weeding is feasible in row sown crop and it depends on the physical condition of soil for running the implement. Mechanical weeding should be done within 20-30 days.

Chemical weed management

The choice of herbicides for weed control in rice depends upon type of rice culture (irrigated or rain fed), rice establishment method (transplanted verses direct seeded), land preparation (lowland or upland) and cultural practices. Appropriate herbicide programme need to be developed for upland rice in terms of doses, time of application and integration with other non chemical methods, other herbicides to optimize weed control. Herbicide phytotoxicity can be reduced by applying them after a germinating rain rather than applying them immediately after seeding. No loss in weed control and in some instances better weed control, has been observed when herbicides are applied at that time (Moody, 1977b). When the herbicide is applied within 3-4 days after seeding, several weeks may pass before there is sufficient rainfall to provide quick germination. During that dry spell, herbicides may breakdown and weed control will be less than desirable than if rain had fallen immediately after seeding.

Pre-emergence application

Several pre-emergence herbicides viz., butachlor, thiobencarbs, pendemethalin, oxadiazon, oxyfluorfen and nitrofen alone or supplemented with hand weeding have been reported to provide a fair degree of weed control in upland rice (Mishra *et al.* 1988; Moorthy and Manna, 1993; Mishra, 1996, Paradkar, *et al*. 1997; Porwal, 1999). However, some difficulties are associated with pre-emergence application of herbicides such as their limited duration of application time (0-5 DAS of crop before emergence of weeds) and lack of soil moisture at the time of herbicide application. Two sprays of oxadiazon @ 0.4 Kg ha^{-1} and oxadiargyl @ 1.0 Kg ha^{-1} (Pre and Post emergence) produced 316 % higher grain yield in comparison to weedy check at Dapoli, Maharashtra (Mane and Raskar, 2002). Chaubey *et al*. (2001) reported that cyhalofop butyl at 80 g ha^{-1} (16DAS) and butachlor at 1.6 kg ha^{-1} (3 DAS) had comparable grain yield with each other and were better in comparison to weedy check at Raipur, Madhya Pradesh.

Sequential application

A study conducted at Central Rice Research Institute, Cuttack by Moorthy and Saha (2002) indicated that quniclorac at 375 g ha^{-1} as preemergence application and butachlor and propanil (at 560 + 500 to 840+840 g ha^{-1}) when applied 10 DAS provided adequate weed control and yield was comparable to hand weeding twice in upland rice. At Raipur, Madhya Pradesh, Kolhe and Tripathi (1998) observed that pre emergence application of anilofos (0.4 Kg ha^{-1}) alone or in combination with pre or post emergence application of 2, 4 -D (0.533 Kg ha^{-1}) or post emergence application of cyhalofopbutyl (0.09 Kg ha^{-1}) produced significantly higher grain yield than weedy check.

Weed management in upland rice under shifting cultivation

Logging in forested upland areas is most often followed by shifting cultivation. Rice is not always grown as monocrop in the uplands. Farmer's sometimes use maize, root crops and vegetables as intercrops with rice or plant them in rotation. These farmer's prepare their scattered fields using traditional slash and burn techniques where they cut, dry and burn trees and bush; plant crops 1-2 years and then move to new areas, allowing the cropped areas to rejuvenate. They usually return to previously cleared areas 3-10 years later. Weeds are the major factor limiting the crop production in shifting cultivation under upland condition; weed infestation is more severe in upland (71%) as compared to wetland (29%) condition (Hazarika *et al.* 2001). Weed infestation in upland shifting cultivation are more due to inadequate land preparation, poor moisture and nutrient content of the soil and alternate, wetting and drying due to erratic nature of the rainfall (Singh, 2001).

Upland rice in hills suffer from mineral deficiencies and toxicities, additionally erosion is a serious problem in high rainfall areas with unstable top soil. The weed management practices that expose soil to erosion or in anyway degrade it are thus in appropriate for suitable crop production in shifting cultivation. (Akobundu, 1993).Weed control in hills is traditionally based on fallowing, slash and burning and hand pulling or shallow hoeing. In areas where fallow periods are drastically declined, farmers adopt tillage and/or herbicides based weed control. Farmer's sometimes use common salt for post emergence control of broad leaved weeds in hills of Nagaland. Application of common salt in extremely acidic soil of hills kills weeds due to exo-osmosis of plant cells. However, application of common salt was not found remunerative (Tabin and Singh, 2008).

Fallow management

Fallow management is an important option for reducing weed burdens by changing factors such as the aeration of the system e.g. flooded to aerobic-and/ or by preventing the production of seeds by weeds during the fallow period. Changing system aeration tends to force major shifts in weed species from one season to the next. Such strong changes in weed flora helps to prevent the build up of any dominant weeds that are favoured by particular set of growing conditions.

One of the most widely used methods of controlling weeds in traditional farming systems is to allow arable land to revert to natural vegetation (bush fallow).Under such circumstances natural selection shifts the balance in favour of perennial plant species, including trees, which then become the dominant species. Such a system suppresses the growth of herbaceous plants, including weeds. Given enough time (up to 10 years) the weed seed population is depleted to such a level that the weeds are not usually a problem in the first year of cultivation after the forest is cleared (Akobundu,1993).

Development of broad spectrum post emergence herbicides, development of weed competitive, allelopathic and herbicide resistance rice varieties, and development of socially acceptable, economically feasible and environmentally sound site specific IWM for upland rice are necessary for successful and economical weed management in upland rice.

REFERENCES

Akobundu IO 1993. Integrated weed management techniques to reduce soil degradation, IITA Research No.6 (March):11-16

Ampong-Nyarko K and De Datta SK 1989. Ecophysiological studies in relation to weed management strategies in rice. Pages 31-45 In Proceedings of the 12 th Asian-Pacific Weed Science Society Conference, Seoul, Republic of Korea.

Angiras MM and Sharma V 1998. Integrated weed management studies in direct seeded upland rice (*Oryza sativa)*. Indian Journal of Weed Science, 30 (1 & 2): 32-35.

Arraudean MA 1995.Upland rice : challenges and opportunities in a less favourable ecosystem. GeoJournal 35(3): 325-328

Chou CH 1998. Adaptive autointoxication mechanisms in rice. In Allelopathy in Rice, Proceedings of Workshop on Allelopathy in Rice, Los Banos, Philippines, Nov 25–27, 1996 Olofsdotter, M.O., Ed.; International Rice Research Institute: Los Banos, Philippines,p.99–115.

Choubey MK, Kolhe SS and Tripathi RS 2001. Relative performance of Cybalofop butyl for weed control in direct seeded rice. Indian Journal of Weed Science 33 (3 & 4) : 132-135

De Dutta SK 1974. Phillipines Weed Science Bulletin, 4:39-63.

Dilday RH, Lin Jand Yan W 1994. Identfication of allelopathy in the USDA-ARS rice germoplasm collection. Ausralian Journal of Experimental Agriculture 34: 901–910.

Dilday RH, Nastasi P, Lin J, Smith RJ Jr.1991. Allelopathic activity in rice (*Oryza sativa* L.) against ducksalad [*Heteranthera limosa* (Sw.) Willd.]. In Proceedings of ustainable Agriculture for the Great Plains, Beltsville, MD, Jan 19–20 1989; Hanson, J.D., Ed.; USDA-ARS: Springfield, MD, 1991; ARS-89, 193–201.

Ebana K ,Yan W, Dilday RH, Namai H and Okuno K 2001. Variation in the allelopathy effect of rice with water soluble extracts. Agronomy Journal. 93:12–16.

Friesen GH and Korwar GR 1983. A decade of weed research in the Indo Candian Dryland project, Weed Research, 23:365-371

Garrity DP, Movillon M and Moody K 1992. Differential weed suppressing ability in upland rice cultivars. Agronomy Journal 84: 586-591.

Goldberg DE and Landa K 1991. Competitive effect and response hierarchies and correlated traits in the early stage of competition. Journal of Ecology, 79:1013-1030.

Hassan SM, Rao AN, Bastawisi AO, and Draz AE 1998.Weed management using allelopathic rice varieties in Egypt. Proceedings of International Workshop on Constraints, Opportunities and Innovations for Wet-Seeded Rice, Bangkok, Thailand, 31 May–3 June 1994;

International Rice Research Institute: Los Banos, Phillipines, 1998; 257–269.

Hazarika UK, Singh R and Singh NP 2001. Ecological distribution of weed flora in Meghalya: their intensity of occurrence in field crops and management. Division of Agronomy, ICAR Research Complex for NEH Region Umiam-793103, Meghalaya, India pp.3.

Hill JE, Bayer DE, Bcchi S and Clampett WS 1991. Direct seeded rice in the temperate climates of Australia, Italy and United States. In "Direct-seeded Flooded Rice in the Tropics." International Rice Research Institute, Los Banos, Philippines.

Holm LD and Herberger JP 1969. Proceeding of Asian-Pacific Weed Science control. Inter; 2nd Los Banos, pp. 1-14.

Jannik JL, Orf H, Jordan NR and Sha RG 2000. Index selection for weed suppressive ability in soybean .Crop Science, 40:1087-1094.

Jennings PR and Aquino RC 1968. Studies on competition in rice 111. The mechanism of competition among phenotypes. Evolution, 2: 529-542.

Kar G, Singh Ravender and Verma HN 2003. Crop diversification Technology in rainfed upland rice area area of eastern India for increased productivity and rain water use efficiency, Research Bulletin No. 13/2003, water Technology Centre for eastern Region, Bhubneswar-751023, Odisha, India

Kim KU, and Shin DH(2005). allelopathic research and development–a world view on breeding of allelopathic rice. In proceedings of the 20 th Asian-Pacific weed Science Society Conference 7-11 November, 2005. Ho Chi Minh City, Vietnam

Kim KU and Shin DH 1998. Rice allelopathy research in Korea. In Proceedings of the Workshop on Allelopathy in Rice; Olofsdotter, M., Ed.; 25–27 Nov. 1996 International Rice Research Institute: Los Banos, Philippines p.39–44.

Kolhe SS and Tripathi RS 1998. Integrated weed management in Direct seeded rice. Indian Journal of Weed Science 30 (1 & 2) : 51-53

Ladu M and Singh MK 2006. Crop weed competition in upland direct seeded rice under foothill conditions of Nagaland. Indian Journal of Weed Science 38 (1 & 2) : 133-134

Lakpale SS, Tuteja M, Pandey and Tripathi RS 1994. Effect of planting time and fertility level on grain yield of rice. Indian Journal of Agronomy, 39: 624-626

Longchar TS, Singh MK and Singh NP 2002. Effect of method of sowing and weed control measures on weed growth and yield of rainfed direct seeded upland rice under foot hill condition of Nagaland. Indian Journal of Hill Farming, 15(2):105.

Mane RB and Raskar BS 2002. Effect of sowing dates and weed control measures on drilled rice (*Oryza sativa* L.) Indian Journal of Weed Science 34 (3 & 4): 282-284.

Mishra GN 2003. Weeds and their management in upland rice. Indian Farming (August 2003): 18-21

Mishra GN 1996. Herbicidal control of upland rice weeds, its limit and impact on Agro ecosystem, Farmers and Parliament 31: 15-16

Mishra RK, Deshmukh MR, Paradkar VK and Tewary KL 1988. Efficiency of herbicides in direct seeded rice, Pesticides, 22: 10-14

Moody K 1977b. Weed control in sequential cropping in rainfed lowland rice growing areas in tropical Asia. Paper presented at the Workshop on Weed control in small scale farms during the 6thAsian- Pacific Weed Science Society Conference, 11-17 July 1977, Jakarta, Indonesia. pp.30

Moorthy BTS and Saha Sanjoy 2002. Evaluation of pre and post emergence herbicides for their effects on weeds and upland direct seeded Rice, Indian Journal of Weed Science 34 (3 & 4): 197-200.

Moorthy BTS and Manna GB 1993. Studies on weed control in direct seeded upland rainfed rice. Indian Journal of Agricultural Research , 27: 175-180.

Matsunaka S 1970. Proc. FAO Conference on Weed Control 1st, Davis,California.

Noda K 1977. In integrated control of weeds (J.D.Fryer and Matsunaka,eds.) University of Tokyo Press, Tokyo. pp 17-44

O' Brien DT 1981. Ph. D. thesis, University of the Philippines, Los Banos,Lguna.

Olofsdotter M, Valverde BE and Madsen KH 2000. Herbicide resistant rice (*Oryza sativa* L.): Global implications for weedy rice and weed management. Annals of Applied Biology, 137: 279–295.

Olofsdotter M 2001. Rice-a step toward use of allelopathy. Agronomy Journal93: 3–8.

Olofsdotter M, Navarez D and Moody K 1995. Allelopathic potential in rice (*Oryza sativa* L.) germplasm. Annals of Applied Biology 127: 543–560.

Paradkar MR, Kurchania SP and Tiwari JP 1997. Chemical control of *Parthenium hysteropherus* and other associated weeds in upland drilled rice. Indian Journal of Weed Science 29: 151-154.

Porwal MK 1999.Weed management through herbicides in direct drilled upland rice in rainfed situations of Southern Rajasthan. Indian Journal of Weed Science 31(3 & 4): 196-198

Rao VS 2011. Principles of weed science. Second edition IBH Publishing Company, Oxford pp.47

Roy DK and Mishra SS 1999. Effect of weed management in direct seeded upland rice (*Oryza sativa*) at varying levels. Indian Journal of Agronomy 44(1): 105-108

Sankaran S and Dutta De SK 1985. Weed and weed management in up land rice. Advances in Agronomy, 38(283-337)

Singh NP 2001. Integrated weed management in rice, Indian Farmer's Digest, pp.9-11

Singh B 1988. Effect of weed control methods on performance of rice varieties under upland rainfed conditions of Nagaland. Indian Journal of Weed Science 20: 51-54

Singh S, Sinha KK, Mishra SS and Thakur SS 1989. Crop weed competition studies in direct seeded upland rice under North Bihar conditions. Indian Journal of Weed Science21:15-18.

Singh SR, Singh V, Singh UN and Singh TK 1993. Tillage-cum-weed management studies in upland rainfed rice. Recent Advances in Dryland Agriculture, Scientific Publishers, Jodhpur.

Singh T, Singh MK and Singh SR 2008. *Climate change and food security* (Eds., M. Datta, N.P.Singh and Er. D.Daschaudhuri) New India publishing Agency, New Delhi pp. 129-147

Smith EV and Fick GL 1973. Journal of American society of Agronomy, 29: 1007-1013.

Smith RF and Reynolds HT 1966. Principal definitions and scope of integrated pest control. In: proceedings FAO symposium on integrated pest control (October 1965) 11-17

Smith RJ 1988. Weed threshold in Southern US rice (*Oryza sativa*). Weed Technology. 1988, 2, 232–241.

Tabin D and Singh MK 2008. Effect of common salt and 2, 4-D Na Salt application on weed growth and yield of upland direct seeded rice, Oryza , 45(4):296-299

Thien TC, DV Chin, TV Hien, NT Nhiem 2005. Evaluation of imidazolinone herbicides for weedy rice (*Oryza sativa*) control in clear field ™ paddy, In Proceedings of 20 th Asian-Pacific Weed Science Society Conference 7-11 November, 2005. Ho Chi Minh City, Vietnam pp.282-288