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# Integration of elements of a farming system for sustainable weed and pest management in the tropics

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**Abstract**

Diversification of agricultural activities that links farm-based enterprises with cultivation of field crops helps the resource-poor farmers in tropics to generate additional income, gainful employment and improve their dietary standards. A farming system approach has been found to be a resource management strategy for achieving economic and sustainable agricultural production, catering to the diverse needs of tropical farm household while preserving the resource base and ensuring high environmental quality. A judicious combination of any one or more of the farming enterprises like poultry rearing, duckery, fish culture, cattle rearing, green manuring and culture of bio-fertilizers contribute significantly for weed and pest management in field crops. Cropping system strategies like rotation of crops in sequence, intercropping and mulching do influence the weed–pest complex of crops. All these elements alter the weed flora in cropped fields through their feeding habits, allelopathic or allelomediatory principles in their excreta, suppression through physical interference like shading and altered ecology. Some of these elements also supplement pest management directly by virtue of their predatory behaviour or indirectly through suppression of weeds that serve as alternate hosts and by inducing fast and robust crop growth. Field experiments in Faculty of Agriculture, Annamalai University, India have revealed such beneficial interactions among component elements of different farming systems, viz., rice + fish + poultry, rice + azolla + fish, greenmanure–rice, rice–pulse, goat rearing + sorghum and cotton intercropped with pulse. All these approaches along with similar strategies involving other farming elements are discussed here.


*Keywords:* Farm components; Animal; Agro-forestry; Integrated weed and pest management

## 1. Introduction

Managing weeds is preferred through a systems approach that would consider all appropriate tools instead of depending on a single technique. An integrated approach comprising two or more tools or strategies has to be evolved for an efficient weed management system. Such an integrated weed control needs to aim at a wholistic management of the total vegetation complex or habitat management instead of revolving around weed control alone (Zimdahl, 1999, pp. 516–517). Increasing environmental awareness and concern among the public makes it necessary for agricultural scientists and farmers to put into practice and demonstrate responsible farm management systems that will address the sustainability concept and link environment and farming, as has been attempted by organizations such as Linking Environment and Farming, European Initiative for Sustainable Agriculture, etc. (Naylor and Drummond, 2002, pp. 302–310). Human populations in all the tropical nations show an increasing trend, demanding production of more food. This steady explosion of population and shrinkage of cultivated lands due to intense industrialization and urbanization leave very little scope for increasing the farm size. If horizontal expansion of land for agriculture is not possible, then vertical expansion through integrating appropriate farming components or elements such as poultry rearing, fish culture, goat rearing, apiary, etc with traditional cropping offers excellent scope for augmenting food production. This integrated farming system approach assumes greater significance especially with small-farm holders as it offers

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additional benefits such as complementary weed and pest control, minimized agrochemical use and environmental degradation, enhanced dietary standards of resource-poor farmers, generation of gainful employment and maintenance of sustainability (Kathiresan et al., 2001; Gunasekaran and Kathiresan, 2003). Constrained with limited resources, an average farmer of a developing country could neither afford to take big risks nor opt for technologies associated with large external inputs. Accordingly, research on vegetation management strategies capable of minimizing weed infestation and simultaneously favouring sustainable crop production that is economical and eco-friendly needs attention (Akobundu, 2000). Cropping system strategies involving crop rotation, intercropping and off-season land management (with ploughing or raising green manures) do alter weed–pest complex of crops. The contribution of such farming elements on the weed–pest complex by virtue of the feeding habits of the organisms concerned, allelopathic or allelomediatory principles in their excreta or metabolites, smothering growth habits deserves a thorough understanding for use as a tool in integrated weed management (IWM) and integrated pest management (IPM). Ancillary benefits like increased energy efficiency and increased biodiversity, both on – farm and in the surrounding habitat, resulting from IWM has been established (Swanton & Murphy, 1996). Linking integrated farming approaches to IWM and IPM helps to address the bio-diversity concerns with a simultaneous reduction in agrochemical use, especially under conditions prevalent in small-farm holders. Several farm components that serve as elements for the integrated farming system have been studied for their contribution to IWM. Some of these are discussed below.

## 2. Cropping components and IWM

Intensive agriculture widely practised in the developing countries of tropics involves temporal diversification (crop rotation) and spatial diversification (inter cropping) of crops. These strategies are followed mainly with the objective of increasing the cropping intensity and land use. However, complementary benefits such as reduced weed density and biomass due to systems approach in cropping have been increasingly observed by many researchers. Crop rotation with sunflower, soybean or cotton was shown to deplete the seed bank of *Striga hermonthica* by about 30 per cent annually in maize or sorghum in Northern Ghana (Sprich, 1994). In a 5-year study at IITA, Nigeria, *Pueraria phaseoloides* and *Leucaena leucocephala* were shown to reduce the weed seed bank when used as live mulch and alley crop, respectively in a planted fallow system compared with that of a natural fallow (Ekeleme et al., 2000). In India, off-season land management contributed significantly to reducing the weed biomass in rice and cotton that followed in sequence in the Cauvery delta region (Vijayabaskaran and Kathiresan, 1993). Introduction of sugarcane between rice and wheat in sequence posed the threat of *Cyperus rotundus* in the following rice crop but helped to suppress *Phalaris minor* in wheat (Singh et al., 2001). A 3-year study of weed management in the rice — mung bean cropping sequence at Annamalai University, with the treatments repeated in one and the same plot in every season, revealed that the preponderance of lowland weeds like *Cyperus difformis* was reduced by the introduction of relay crop of mung bean in sequence (Kathiresan, 2002). Raising a green manure crop of *Sesbania aculeata* in the off-season (May–July) and ploughing it in situ at the age of 45 days, before the cultivation of rice in the first (August–January) as well as the second (January–April) season, helped in reducing weed competition (Fig. 1) in both the rice crops (Gnanavel and Kathiresan, 2002). Off-season land management such as summer ploughing or raising green manure contributed significantly to depleting the weed seed reserves in the soil whereas rotation of an upland crop like mung bean with rice interrupted the weed flora in lowland with widely varying field conditions. With regard to spatial diversification, intercropping has been shown to complement weed management in several tropical countries. In Kenya, intercropping maize with beans suppressed weeds (Chui et al., 1997; Mania and Drennan, 1997). Sudan grass was intercropped in maize as a trap crop for *Striga hermonthica* and uprooted after 30 days (Oswald et al., 1997).

In India, intercropping pearl millet suppressed weeds in pigeonpea by 50.8 per cent (Tewari and Rathi, 1997). Contribution of intercrops in managing weeds has been reported under varied cropping patterns in the tropics (Mania et al., 1996; Chui et al., 1997; Chivinge et al., 2001; Khan et al., 2001; Sundari and Kathiresan, 2002). Weed smothering by intercrops (Table 1) is chiefly attributed to shading and interference through allelo compounds.

## 3. Organic inputs and IWM

Use of some organic inputs in small farm holdings in developing countries of the tropics has yielded considerable

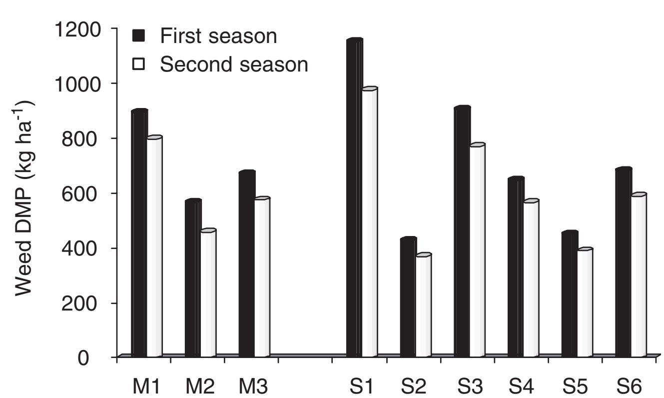


Fig. 1. Off-season land management and weed control in rice–rice sequence.
*Treatments:* M1—Off-season fallow; M2—Off-season ploughing; M3—Green manure raising; S1—Untreated control; S2—Twice hand weeding; S3—Pressmud at 10 t ha$^{-1}$; S4—Azolla at 1 t ha$^{-1}$; S5—Pressmud at 10 t ha$^{-1}$ + Azolla at 1 t ha$^{-1}$; S6—Butachlor at 1.25 kg ha$^{-1}$.

Table 1
Effect of integrated weed control measures in irrigated sorghum

| Treatments | Total weed dry weight $m^{-2}$ at 60 DAS (g) | Weed control index at 60 DAS (%) |
|---|---|---|
| Unweeded control | 137.1 | — |
| Hand weeding twice | 8.5 | 93.8 |
| Metolachlor (1.5 kg $ha^{-1}$) | 23.2 | 83.0 |
| Metolachlor + hand weeding | 18.7 | 87.6 |
| Metolachlor + intercropping of blackgram | 10.0 | 92.7 |
| Metolachlor + mulching sugarcane trash at 5 t $ha^{-1}$ | 16.9 | 87.2 |
| Mulching alone (sugarcane trash at 5 t $ha^{-1}$) | 62.0 | 54.7 |
| Intercrop alone (blackgram) | 53.2 | 61.1 |
| S.Ed | 4.14 | — |
| LSD ($P = 0.05$) | 8.45 | — |

benefits in terms of reducing weed infestation. Such agronomic inputs include mulches, bio-fertilizers and organic manures. The role of mulches in suppressing weeds of cropped fields has been brought out in studies at IITA, Nigeria (Kamara et al., 1997) and at Annamalai University, India (Vijayabaskaran and Kathiresan, 1993; Sundari and Kathiresan, 2002). Bio-fertilizers like Azolla, a fern that fixes atmospheric nitrogen in the soils, has been used in lowland rice farming systems to fix atmospheric nitrogen. However, the formation of a thick mat of thallus by the fern on the standing water surface (in lowland rice, water is often impounded to retain a standing water column until a fortnight before crop harvest) in the field curtails light interception by the weed seeds and seedlings, leading to weed suppression (Kathiresan et al., 2001). Use of some organic manures like the cane sugar factory bi-product filter pressmud, suppresses weed emergence in lowland rice by virtue of its acidic nature and allelopathic metabolites. Further, pressmud was also observed to enhance the activity of acetamide herbicides in rice (Arulchezian and Kathiresan, 1990; Vijayabaskaran and Kathiresan, 1993; Parthiban and Kathiresan, 2002).

## 4. Agro-forestry components and IWM

Mulching with pruned leaves of multi-purpose trees *Gliricidia sepium* and *Flemingia macrophylla* effectively reduced weed density and biomass in maize (Kamara et al., 1997). Leaves of *Eucalyptus globulus* and *Leucaena leucocephala* when incorporated as green leaf manure in transplanted rice at 5 t $ha^{-1}$ reduced weed infestation (Table 2) through allelopathic metabolites and performed comparably with the traditional rice herbicide butachlor at 1.5 l $ha^{-1}$ (Parthiban and Kathiresan, 2002). Evaluation of oil palm empty shift bunch fibre mats for use as mulch-o-mat and eco-mat in rubber plantations in Malaysia revealed 86 per cent control of *Pennisetum polystachion* 12 months after treatment (Faiz, 2003).

## 5. Animal components and IWM

An integrated farming system is perceived to be a feasible option for small-farm holders offering scope for higher productivity from different enterprises combined with higher economic returns, reduced cost of inputs, reduced agrochemical use in terms of fertilizers and plant protection chemicals, better employment generation and enhanced fertility status of the soil. In lowland rice culture, integration of fish suppressed the weeds effectively and minimized the incidence of pests and diseases (Dan et al., 1997). Traditional Asian farming in many countries includes an integrated approach and serves as a model for true environmental conservationist agriculture.

Table 2
Effect of incorporation of some plant materials on rice field weed DMP and WCI

| Treatment | Weed DMP (kg $ha^{-1}$) | WCI (%) |
|---|---|---|
| Untreated | 1158.0 | |
| Pressmud at 10 $ha^{-1}$ | 870.0 | 29.90 (24.85) |
| Neem cake at 0.4 t $ha^{-1}$ | 879.0 | 29.47 (24.15) |
| Eucalyptus leaves at 5 t $ha^{-1}$ | 657.0 | 41.11 (43.25) |
| Subabul leaves at 5 t $ha^{-1}$ | 689.5 | 39.94 (40.05) |
| Calotropis leaves at 5 t $ha^{-1}$ | 815.5 | 33.28 (30.75) |
| Twice hand weeding | 427.0 | 52.61 (63.10) |
| Butachlor at 1.25 kg $ha^{-1}$ | 751.5 | 36.33 (35.10) |
| CD ($P = 0.05$) | 60.5 | 2.95 |

Figures in parentheses are original values.

Integrated rice and duck farming is widely practised in Vietnam and integrating ducks reduces *Echinochloa crus-galli* and *Monochoria vaginalis* drastically (Furuno, 2001).

Long-term effects of integrating fish and poultry components with lowland transplanted rice have been studied at Annamalai University, where treatments comprising rice alone, rice + fish, rice + poultry and rice + fish + poultry were compared for 8 years in the same location. Results indicated that fish and poultry components independently contributed for 26 and 24 per cent weed control, respectively, and fish + poultry together contributed for 30 per cent weed control (Table 3). The same study also proved that application of sugar factory bi-product pressmud as organic manure with dual culturing of bio-fertilizer azolla in the integrated rice + fish + poultry farming system could offer 69 per cent weed control, paving the way to dispense with herbicide application (Gunasekaran and Kathiresan, 2003). Among

Table 3
Influence of farming elements on rice weed dry matter (kg ha$^{-1}$) and weed control index (%) (average of two seasons)

| Treatment | Weed dry matter (kg ha$^{-1}$) | Weed control index (%) |
|---|---|---|
| Rice unweeded | 1091.4 | |
| Rice + fish (unweeded) | 873.8 | 26.53 (19.95) |
| Rice + poultry (unweeded) | 900.2 | 24.74 (17.52) |
| Rice + fish + poultry (unweeded) | 657.8 | 39.08 (39.73) |
| Rice + fish + poultry—twice hand weeded | 315.1 | 57.5 (71.14) |
| Rice + fish + poultry—butachlor at 1.25 kg ha$^{-1}$ | 458.2 | 49.62 (58.03) |
| Rice + fish + poultry—Azolla at 1 t ha$^{-1}$ + pressmud at 10 t ha$^{-1}$ | 336.8 | 56.25 (69.14) |
| S.Ed | 40.9 | 3.27 |
| CD ($P = 0.05$) | 82.2 | 6.58 |

Figures in parentheses indicate original values.

the three herbivorous fish species compared (*Ctenopharyngodon idella* (grass carp), *Cyprinus carpio* (common carp) and *Sarotherodon* sp. (Tilapia)) grass carp was observed to be a more voracious feeder on rice weeds (Kathiresan, et al., 2005). The impact of poultry component on rice weeds was attributed to the acidic nature and biochemical fractions of fresh poultry waste that suppressed germination of rice weeds like *E. crusgalli* (Table 4). Integrating cattle grazing and sylviculture in dry lands is another approach widely practiced in tropics. Cattle grazing depletes the seed bank or rejuvenability of underground propagules of weeds over a period of time and hence holds scope for integration in widely spaced plantations or in the off-season preceding field crops. Studies in Sri Lanka established such a weed control impact of cattle grazing in rubber plantations (Senanayake, 1996) and experiments at Annamalai University have shown reduced weed competition in maize due to repeated cattle grazing during the preceding off-season.

## 6. Horticulture component and IWM

Integrated Weed Management becomes most suitable for managing aquatic systems with infestations of problem weeds such as *Eichhornia crassipes.* The use of herbicides affects on water quality and associated flora and fauna whereas exclusive dependence on bio-control using insects is a relatively slow process. Thus, often integration of a short-term control measure with insect bio-control is recommended. Allelopathic inhibition of water hyacinth by the dry leaf powder of the Indian medicinal herb *Coleus amboinicus/aromaticus* appears to offer a promising lead in this direction (Kathiresan, 2000) and integrating this allelopathic plant product with bio-control agent *Neochetina eichhorniae/bruchii* was successful in controlling the weed within 45 days (Kathiresan and Gnanavel, 2005).

## 7. IWM and weed shift

Some of the integrated approaches have been found to assist in preventing a shift in weed flora on a long-term basis whereas a few others were reported to favour.

Table 4
effect of fresh poultry manure on germination of *E. crusgalli* on 7 DAS

| Treatments | Seed germination (%) |
|---|---|
| Untreated control | 71.56 (90.00) |
| 1% concentration | 64.89 (82.00) |
| 2% concentration | 58.69 (73.00) |
| 3% concentration | 51.94 (62.00) |
| 4% concentration | 45.00 (50.00) |
| 5% concentration | 40.39 (42.00) |
| S.Ed | 2.00 |
| CD ($P = 0.05$) | 4.00 |

Figures in parentheses are original values before angular transformations.

However, such shifts could be location specific, favoured by other factors such as climate. Integration of hand weeding supplement with herbicides in the rice-mung bean cropping sequence retained the eco-balance in terms of floristic composition of the weed flora, whereas sole dependence on hand weeding led to a shift towards grassy weeds by virtue of their morphological similarity with crop and dependence on herbicides resulted in the dominance of persistent perennials, after 3 years of continuous cropping (Kathiresan, 2002). A change in the land use pattern in Hawaii from sheep grazing to cattle ranching allowed the shrub *Ulex europaeus* to invade.

Cattle trampling resulted in micro sites for seedling establishment and cattle did not graze on this species as effectively as sheep (Binggelli, 2000). In Australia, the replacement of sheep by cattle coupled with frequent above average wet years favoured invasion by *Acacia nilotica* (Tiver et al., 2001).

## 8. IWM and IPM

Integrated weed management also contributes significantly to IPM. Many weed species have been observed to serve as alternate hosts for insect pests. *Leersia hexandra* and *Echinochloa crusgalli*, because of their higher content of nitrogen, sugars and amino acids and lesser content of potash, silica and phenols, served as most preferred alternate hosts for rice leaf folder *Cnaphalocrocis medinalis*

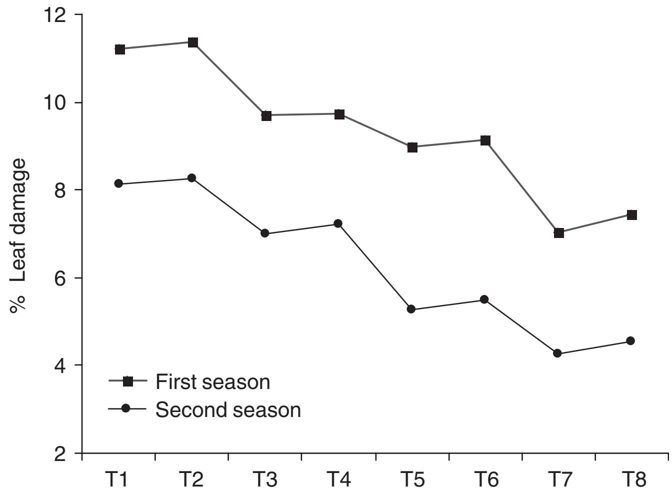


Fig. 2. Farming elements and pest incidence in rice.
*Treatments:* $T_1$—Rice (inorganic fertilizers + chemical pest control); $T_2$—Rice (inorganic fertilizers + organic pest control); $T_3$—Rice (organic manuring + chemical pest control); $T_4$—Rice (organic manuring + organic pest control); $T_5$—Rice + fish + poultry ($T_1$); $T_6$—Rice + fish + poultry ($T_2$); $T_7$—Rice + fish + poultry ($T_3$); $T_8$—Rice + fish + poultry ($T_4$).

(Hariprasad, 2000). Carpet weed *Trianthema portulacastrum* was observed to host the caterpillar of a serious pest *Hymenia recurvalis* (Sivakumar and Radhakrishnan, 2000). The integrated rice + fish + poultry farming system studied at Annamalai University showed an ancillary advantage of reduced pest incidence in rice as shown in Fig. 2 (Kathiresan and Jayakanth, 2006).

## 9. Conclusion

The public perception about agriculture as a polluter of rural farm side makes it imperative to include sustainability concepts in farm management systems that will ultimately reduce pesticide use. Linking elements of farming as components in integrated weed management in small-farm holdings could help in broadening its impact over and above weeds to the total vegetation complex or habitat management, with the possibility of additional benefits such as increased economic returns, enhanced dietary standards of resource-poor farmers, improved soil fertility and reduced agro-chemical use.


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