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Weed Diversity and their Management in Major Rice-based Cropping Systems in India

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ABSTRACT

Weeds are unwanted and undesirable plants that interfere with cultivated crops for utilization of natural resources such as nutrients, water, and light, space, causing harbor of insect pests and disease adverse allelopathic effects and increasing cost of production indirectly, reducing crop yield. India is an agrarian country, where cropping systems form the backbone of Indian agriculture. Every cropping system has its associated weeds, and to manage these weeds requires a specific crop management approach. The main rice-based cropping systems in India, such as rice-wheat, rice-rice, rice-pulse, rice-maize, and rice-oilseed, have been pivotal in ensuring food security. However, these systems face significant challenges due to weed infestations, leading to yield losses ranging from 13% to 97%. Weeds like grass, sedge and broad-leaf weed varieties pose a substantial threat to these crops, particularly in direct-seeded conditions. To manage weeds effectively, various approaches are employed, including crop rotation, tillage, herbicide application, and intercropping. For instance, in rice-wheat systems, zero-tillage practices, crop residue mulch, and early sowing help to reduce weed emergence. In rice-pulse systems, pre-emergence herbicides, hand weeding, and intercropping prove effective. Maize-based systems benefit from tillage, mulching, and planting at closer spacing. Weed management is critical to sustaining rice-based cropping systems and ensuring food security in India. Tailored strategies that consider crop-specific challenges are essential to mitigate yield losses and maintain agricultural productivity.

KEYWORDS: Rice-based cropping system, herbicide, weed management, yield

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1. INTRODUCTION

Rice (*Oryza sativa* L.) is the primary cereal crop grown in more than 100 countries worldwide, serving as the fundamental dietary staple where about 90% is produced and consumed for over half of the global population (Rao et al., 2007). India is the world's 2nd highest producer of rice with a production of 130.29 mt from a cultivated area of 46.38 mha. Rice-based cropping system plays a pivotal role in food production, featuring rice as the primary crop. The higher productivity and stability of the rice-based cropping system provide ample employment and income generation opportunities to rural masses besides ensuring food security. To satisfy the needs of a growing population, India must focus on enhancing crop productivity. This can be achieved by identifying and addressing the obstacles that impede farmers from achieving high yields. In India, weed is one of the major biological constraints that limit crop productivity, input-use efficiency and profitability in rice-based cropping systems. Continuous cultivation of rice-wheat cropping sequence favoured the intensification of grassy weeds (Bhatt et al., 2016). Monocropping system favours certain noxious weed species to become dominant in a particular cropping system (Chauhan et al., 2012). They compete with crops for natural resources i.e. light, nutrients, water, and space besides being responsible for reducing the quantity and quality of agricultural productivity (Rao and Nagamani, 2013; Rao et al., 2014.). Weeds are undesired and unwanted plants that negatively impact on human welfare by interfering with the harbor of insect-pests and disease causing organisms, agents causing adverse allelopathy effect (Rao, 2014). Weeds are one of the major issues in agricultural production because of the rise in woody species (Ghersa et al., 2002), herbicide-tolerant species (Hyvonen and Salonen, 2002), and herbicide-resistant biotypes (Heap, 2020) and also because of the negative impact on biodiversity (Satorre et al., 2020) and environmental pollution (Hunt et al., 2017). Among rice based cropping system rice-rice, rice–wheat, rice-maize, rice-pulse, rice–jute, rice-wheat-pulse, rice-oilseed, rice-mustard, rice- pulse/oilseed as paira cropping/utera (lathyrus/lentil/mustard), rice-potato-summer rice are predominant. Each cropping system comes with its unique weed flora, biodiversity and management challenges, necessitating tailored crop management strategies to effectively control these unwanted plants with robust Crop management practices like crop rotation, tillage practice, crop residue management, mulching, water management and nutrients management application of agrochemicals like herbicide, pesticide, insecticide and other agricultural practices (Jat et al., 2021; Nath et al., 2022). These management approaches influence weed seed banks, and weed flora (Marshall et al., 2003) regulating weed dynamics process (weed establishment, competition, dispersion, herbicide resistance) and weed change patterns (Cordeau et al., 2017). The total annual loss caused by weeds is around 37% (Yaduraju et al., 2006). Under farmer's weed management practices, yield losses range between 13.1% to 22.4%, which need to be reduced by improved weed management practices. In global scale, the yield losses from weeds amounts to 40%, which is more than those coming from collective effect of diseases, insect and pests (Hassan et al., 2005). Crucial weeding interventions have to be done during the early stages of the cropping system, soon after sowing, namely in when plants are still weak competitors. By choosing and implementing the right cropping strategies, farmers can significantly reduce weed pressure, minimize the need for synthetic herbicides, and maintain the productivity and sustainability of their fields. Therefore, identification of system specific problematic weeds and controlling by appropriate combination of strategies management through integrated weed management system (cultural, mechanical, chemical and biological methods) to reduce crop specific weed problem to increase agricultural productivity, profitability by indirectly, sustainability, and reduce environmental impacts.

Table 1: Potential yield loss due to weeds in major crops of India (Rao et al., 2014)

Crop	Yield loss (%)	Crop	Yield loss (%)
Chick pea	10-50	Pea	10-50
Cotton	40-60	Pearl millet	16-65
Finger millet	50	Pigeon pea	20-30
Green gram	10-45	Potato	20-30
Groundnut	30-80	Rice	10-100
Horse gram	30	Sorghum	45-69
Jute	30-70	Soybean	10-100
Lentil	30-35	Sugarcane	25-50
Maize	30-40	Vegetables	30-40
Niger	20-30	Wheat	10-60

2. PREDOMINANT WEED FLORA IN RICE–RICE CROPPING SYSTEM

Rice-rice cropping system mainly practices in Uttar Pradesh, Andhra Pradesh, Kerala, Tamilnadu, Chhattisgarh, Punjab, Assam, West Bengal, Orissa, Karnataka, and Gujarat. Due to practice of same crop in same land promote a rich diversity of weed species that may cause yield loss upto 50–90% if weeds are not properly controlled (Chauhan and Johnson, 2011; Singh et al., 2005). It may go up to 97% in upland rice (Singh et al., 1988), 12–70% in transplanted rice and 85% in wet seeded rice (Singh et al., 2011). Major grassy weeds and sedges commonly associated with rice cultivation include barnyard grass (*Echinochloa colona*), para grass (*Brachiaria mutica*), Chinese sprangletop (*Leptochloa chinensis*), rice flat sedge (*Cyperus iria* L.), purple nutsedge (*Cyperus rotundus*), yellow nut sedge (*Cyperus esculentus*) broad-leaved weeds include horse purselane (*Trianthema portulacastrum* L.), dayflower (*Commelina benghalensis* L.), alligator weed (*Alternanthera philoxeroids*), water primrose (*Ludwigia parviflora*), native gooseberry (*Physalis minima*), pink node flower (*Caesulia axillaris*), and blistering ammania (*Ammania multiflora*). *Cynodon dactylon* poses a significant challenge in fields practicing permanent zero tillage (ZT) within the eastern IGP (Jat et al., 2010). Generally, weed-related issues are more pronounced in direct-seeded rice (DSR) when compared to transplanted conditions (Chhokar et al., 2014). Wild rice (*Echinochloa colona*) is emerging as a major problem in direct-seeded rice (Rao and Nagamani, 2007; Rao et al., 2007). The weeds and the crop emerge at the same time with weeds growing more quickly (Rao et al., 2007), leading up to 50–90% yield reduction if weeds are not timely managed (Chauhan and Johnson, 2011; Singh et al., 2005)

Continuous submergence of the crop successfully controls the weed population and inhibits their germination in transplanted rice fields (Subramanayam et al., 2007). Reports highlighted that the combination of intensive puddling with submergence resulted in the lowest weed dry weight, at 6.63 gm^{-2}. Practices like soil solarization, planting competitive crop varieties, preparing stale seedbeds, applying mulch, proper fertilization, and practicing intercropping have been found effective for weed management in aerobic rice systems. The rice-sesbania co-culture and killing with 2, 4-D ester at 0.5 kg ha^{-1} suppress the growth of weeds and is highly effective in controlling both broad-leaved weeds and sedges, but less effective for grassy weeds. However, hand weeding at 20 and 40 DAT gave the highest weed control efficiency with the highest rice grain yield (5.08 t ha^{-1}) (Rekha et al., 2002; Pal et al., 2009). According to Thiyagarajan et al. (2002), the use of cono-weeder led to a 10% boost in grain yield during the wet season, whereas it was only 3% higher in the dry season compared to the conventional weeding method. In rice nurseries, the use of effective herbicides such as pretilachlor+safener (Rao and Moody, 1988), cyhalofop-butyl (Jayadeva et al., 2002; Sharma et al., 2004) and propanil in combination with hand-weeding results in healthy rice seedlings for transplanting. Rice ratooning or re-sprouting poses a significant challenge in no-till rice-rice as well as rice-pulses farming systems in eastern Gangetic plains and peninsular India. Application of pyrazosulfuron ethyl @ 20 or 25 g ha^{-1} at 3 or 10 DAT significantly reduced the weed density and weed dry matter in transplanted rice during the *kharif* season (Chopra and Chopra, 2003; Shekhar et al., 2004). Bispyribac sodium 10% SC @ 25 g a.i. ha^{-1} at 15–25 DAS is effective in controlling all three types of weed flora (grasses, broadleaved and sedges). Saha and Rao (2009) recorded the highest weed control efficiency (95.2%) with the application of bensulfuron methyl @60 g ha^{-1} at 20 DAS. Subramanian et al. (2006) noted that higher grain yield (5744 kg ha^{-1}) with the application of pretilachlor with safener+dhaincha intercropping+azolla dual cropping on 30 DAS in wet seeded rice.

3. PREDOMINANT WEED FLORA IN RICE-WHEAT CROPPING SYSTEM

In India, the rice-wheat cropping system is the most prevalent sequence covering around 10.5 million ha mainly in the Indo-Gangetic Plains (IGP) (Jat et al., 2013). The advent of the Green Revolution brought about a significant surge in wheat production in this region. However, the dwarf wheat variety used in this revolution is more susceptible to weed infestation, particularly when nutrient and water resources are abundant. Weeds typically pose a formidable challenge to wheat cultivation, potentially causing 60% reduction in grain yield under conventional tillage and 70% in zero tillage conditions (Jain et al., 2007) if not effectively managed at critical stages. The major weeds commonly found in wheat fields include little seed canary grass (*Phalaris minor*), strawberry clover (*Trifolium fragiferum*), common lamb's quarters (*Chenopodium album*), common vetch (*Vicia sativa*), black nightshade (*Solanum nigrum*) and toothed dock (*Rumex dentatus*) in varying levels of abundance. One strategy to mitigate the weed problem in wheat is to optimize water management during rice cultivation, which can prove beneficial in reducing the presence of weeds like *Rumex*, as they tend to thrive predominantly in wet soil conditions.

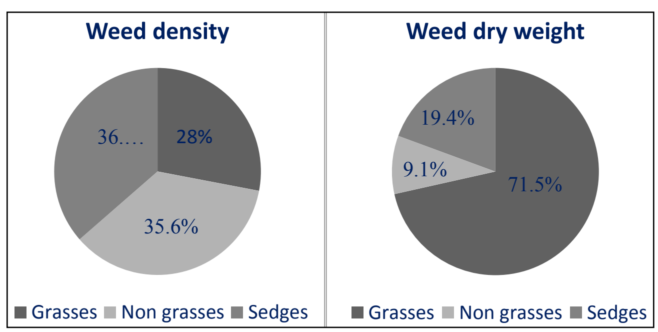

Figure 1: Relative weed density and dry weight of weeds in rice-wheat cropping system

It is imperative to implement weed control measures 15–45 days after wheat sowing as this is the critical period for weed interference. The adoption of zero tillage practices and the retention of crop residues on the soil surface have proven to be highly effective methods for reducing the germination of weeds such as *Phalaris, Chenopodium, Physalis, Anagalis*, and others. For zero-tilled wheat, the use of rice residue mulch @ of 6–10 t ha^{-1}, coupled with early sowing, resulted in the reduction of little seed canary grass emergence by more than 80% (Kumar et al., 2013). Effectively managing water during rice cultivation can also play a beneficial role in decreasing the populations of *Rumex* in wheat, as it primarily thrives in moist soil conditions. Under transplanted rice, application of butachlor @ 1.5 kg ha^{-1} at 3 DAT followed by 2 hand weeding at 30 and 60 DAS produced significantly higher grain yield than in WSR (wet seeding in puddled soil) with cyhalofopbutyl @ 100 g ha^{-1} and DSR (dry seeded rice in unpuddled soil) with pendimethalin 1 kg ha^{-1} under rice-wheat cropping system (Singh et al., 2005). In ZT wheat, pre-plant application of non-selective systemic herbicide glyphosate @ 1 kg a.i. ha^{-1} at 1-7 DBF effectively controls weeds. Effective control of annual grassy weeds in wheat was achieved by application of post-emergence herbicide clodinafop (Topik) 60 g a.i. ha^{-1} or sulfosulfuron (Leader) 25 g a.i. ha^{-1} following the first irrigation at 30 DAS (Gopal et al., 2019). Application of isoproturon+2, 4 D (0.75+0.6 a.i. kg ha^{-1}) produced a higher yield (3.89 t ha^{-1}) and B:C ratio (2.59) in ZT wheat (Singh et al., 2010). A report stated that clodinafop @ 60 g, sulfosulfuron @ 25 g and fenoxaprop-p-ethyl @ 100 g ha^{-1} increased the yield of wheat by 41.9, 43.7 and 39.9% respectively over the weedy check (Walia et al., 2006).

4. PREDOMINANT WEED FLORA IN PREDOMINANT WEED FLORA IN RICE –MAIZE CROPPING SYSTEM

Maize-based cropping systems are prevalent on a large scale, particularly in the central and northern parts of the country. The low productivity of maize in India can be attributed to several limiting factors, of which poor weed management poses a major threat to crop productivity. The most important weeds that can be associated with maize-based cropping systems are *Echinochloa colonum, Digitaria sanguinalis, Dactyloctenium aegyptium, Eleusine indica, Setaria glauca, Sorghum halepense, Panicum spp. Cynodon dactylon, Digitaria setigera,* among grasses; *Ageratum conyzoides, Galinsoga parviflora, Commelina benghalensis, Undernia cilata, Polygonum hydropiper, Euphorbia geniculata, Oxalis latifolia, Celosia argentea, Cleome viscose, Sidaacuta, Aschynomene indica, Acanthospermum hispidum, Portulaca oleracea, Phyllanthus niruri, Amaranthus viridis, Acalypha indica, Tridax procumbens, Ipomoea pestigridis, Parthenium hysterophorus* and *Euphorbia hirta* among non-grassy weeds and *Cyperus rotundus* and *Cyperusiria* among sedges that reduce the maize yields by 27–60%, depending upon the growth and persistence of weed population (Rout and Stapathy, 1996; Lamani et al., 2000). In the rainy season, it was reported that the emergence of maize and weeds was simultaneous and the first 20–60 days was the most critical period of competition for the crop (Porwal, 2000; Nayital et al., 1989).

The agronomic practices, viz. tillage and inter-cultivation, intercropping, mulching, cover crops, crop rotation, higher seed rate, planting at closer spacing, nutrient management, planting methods, and other agro-techniques are used for weed management in maize-based cropping systems. Sharma et al. (2000) opined that hoeing at 15 DAS effectively controlled the weed population at 30 DAS which was less than half (23–32 weeds m^{-2}) as compared with no intercultural operation (67–70 weeds m^{-2}). The intercultural operations like mechanical weeding or two-hand weeding at 20–30 and 35–45 DAS effectively minimized the weed population and increased maize yield (Saikia and Pandey, 2001). Saini et al. (2013) revealed that soybean intercropping +one mechanical weeding (20 DAS) recorded significantly lowest weed dry weight, higher yield attributes and maize equivalent yield which was at par with 2 mechanical weedings (20 and 40 DAS)+mash intercropping in maize. Rani et al. (2011) reported that application of sulfosulfuron 15 g ha^{-1}+imazethapyr 25 g ha^{-1} as pre-emergence with hand weeding at 40 DAS was found to be effective and economic weed management practice for irrigated sweet corn during Rabi season. Walia et al. (2006) reported that the application of atrazine+alachlor @0.50+0.75 kg ha^{-1} fb one HW proved to be significantly superior with the highest weed control efficiency of 89.4%.

5. PREDOMINANT WEED FLORA IN RICE–OILSEED CROPPING SYSTEM

The critical period of crop weed competition in groundnut is 40–60 DAS, for sunflower 15–25 DAS, soybean 20–45 DAS and for rapeseed mustard 15–40 DAS. The major weed flora dominated in rice–oilseed cropping system are *Echinochloa colona*, *Digitaria sanguinalis*, *Cynodon dactylon, Cyperus rotundus*, *Cyanotis axillaris*, *Ageratum conyzoides*, *Spilanthes paniculata*, *Polygonum plebeium*, *Gnapahalium purpureum*, *Chenopodium album*, *Physalis minima*, *Eclipta alba*, *Cleomevis cosa*, *Ludwigia parviflora*, *Solanum nigrum* and *Indigofera hirsute*, *Melilotus indica*, *Trigonella polycerata*, *Chenopodium album*, *Orobanche aegyptiaca*, *Convolvulus arvensis*, *Dactyloctenium aegypteium*, *Digera arvensis*, *Tridex procumbens*, *Phyllantus niruri*, *Commelina benghalensis*, *Eclipta alba*, *Chenopodium album*, *Parthenium* spp (Mishra et al., 2020; Aruna et al., 2018), yield loss ranges from 13% to 100% depending on the season, cultivars, weed composition and duration of crop weed competition, and the packages of practices adopted (Yaduraju et al., 1980; Kalaiselvan et al., 1994; Rajendran and Louduraj, 1999; and Ghosh et al.,1999). However, Giri et al. (1998) reported that an average yield loss due to weed infestation in irrigated summer groundnut is 89%. Bunch-type cultivars have minimal leaf cover, horizontal growth habits, late seedling emergence and slow initial growth, and poor competitive abilities; the crop-weed competition is at its highest in the early phases. (Sheoran et al., 2015).

According to Jha and Soni (2013), the flatbed method of sowing recorded a higher density of monocot (43.2 no. m^{-2}) and dicot weeds (34.4 no. m^{-2}) whereas, the broad bed furrow method recorded the lowest weed density (25.1 and 18.7 no. m^{-2}) in soybean. Marangoni et al. (2013) revealed that compared to planting in December, November planted soybean cultivars recorded the lowest dry weight of monocot weeds and total weed dry weight at 26 days after emergence and harvest. The optimum time of sowing enhanced crop development and the competitive potential of soybean against the weed population. According to Singh (2006) practicing several cultural methods like solarization, using transparent or black polyethylene film for 30 days before sowing of soybean, decreased the weed germination. Besides, soil solarization using transparent polyethylene for 30 days increased the soybean yield by 90%. Arora and Tomar (2012) reported the lowest dry weight of weeds, the highest WCE (54%) and the highest pod yield from stale seedbed in groundnut. As per the report of All India Coordinated Research Project on Groundnut (2009) weed population in ground nut was effectively managed by pre-emergence application of pendimethalin @ 1.0 kg ha^{-1}+post-emergence application of quizalofop-p-ethyl @ 50 g ha^{-1} at 20 DAS+one hand weeding at 45 DAS. Application of pre-emergence herbicide pendimethalin @ 1.0 kg ha^{-1}+post-emergence application of imazethapyr @ 75 g ha^{-1} at 20 DAS+one-hand weeding at 45 DAS was proved to be the best weed control in groundnut. Degra et al. (2006) showed that reduction in weed density by pre-planting application offluchloralin @ 1.0 kg ha^{-1} followed by one-hand weeding at 40 days after sowing in rice under rice-mustard cropping system. According to Singh et al. (2009) pre-emergence application of isoproturon @ 0.5 kg ha^{-1}+one inter-cultivation at 30 DAS brought a significant reduction in weed density and biomass in rapeseed and mustard in India. According to Reddy et al. (1998) application of anilofos @ 0.4 kg ha^{-1} or butachlor @1.5 kg ha^{-1} or 2, 4-DEE @ 1.0 kg ha^{-1} at 5 DAT was found equally effective in suppressing weed growth and increasing grain yield of *kharif* rice. During *rabi*, application of oxyfluorfen @ 0.15 kg ha^{-1} and metolachlor @ 1.5 kg ha^{1} to sunflower was effective in controlling weeds and resulted in a similar yield to that of hand-weeded (20 DAS) crop in the rice-sunflower cropping system.

6. PREDOMINANT WEED FLORA IN RICE–PULSE CROPPING SYSTEM

India is a major pulse producing country in the world sharing about 35% area and 28% production but the area under pulse production has remained static during the past 30 years Pulses mainly grown as a component crop in the rice-wheat cropping systems in Indo Gangetic Plain (IGP) of India. Continuous practice of rice-wheat cropping system resulted in declining productivity, depletion of soil nutrients and water resources, and frequent outbreaks of pests and diseases, thus emphasizing the need for crop rotation. There is a need to revitalize pulse crops underrice-based cropping system since pulses have the capacity of biological nitrogen fixation (BNF), to improve soil fertility and maintain the long-term sustainability of this production system (Ali and Kumar, 2002). IGP region shows huge potential for expansion of pulses either as a catch crop, sole crop as a component for crop rotation in different cropping systems. Chickpeas (*Cicer arietinum* L.), lentil (*Lens culinaris* L.) and pigeon peas (*Cajanus cajan* L.) are being cultivated as major pulses in IGP of India. Weeds were the major biotic constraints for successful reintroduction and profitable production of pulses (Pande et al., 2000). The initial growth stages of pigeon pea are the most critical stage for weed competition resulting in yield loss up to 90%. Late sowing of chickpeas in a rice-chickpea sequential system exposes chickpeas to greater weed competition. *Chenopodium album* is a major weed of chickpea crop and yield loss can be up to 40%. Lentil is a poor competitor with weed flora due to its slow growth and inadequate weed control may cause yield losses of 20–30%. The predominant weed flora in Rice-pulse cropping system are *Echinochloa colona, Cyperus* sp, *Panicum sp* and *Trianthema portulacastrum* (Reddy et al., 2000), *Paspalum paspalodes*, *Marsilea quadrifolia*, *Eclipta alba, Ephorbia prostrata* and *Alternanthera triandra*, *Leersia hexandra* and *Echinochloa crusgalli*, *Fimbristylis littorali* (Pramanick et al., 2014).

In the rice-greengram cropping system application of pre-emergence (PE) herbicide thiobencarb+2, 4-D in rice followed by one-hand weeding (HW) in succeeding crop greengram resulted in the most effective weed control method (Srinivasan et al., 1991). PE application of pendimethalin @ 1 kg ha^{-1}+HW at 30 DAS resulted in lower weed density and higher WCE at all stages of green gram (Hasanain et al., 2020; Rathika et al., 2023). In zero till sown rice fallow black gram cropping system best combination of weed control was dibbling the seeds three days after application of paraquat @ 0.5 kg ha^{-1} with post-emergence application of either fenoxaprop-p-ethyl @ 75 g ha^{-1} or cyhalofop butyl @ 100 g ha^{-1} on 15 DAS resulted in higher grain yield (Sasikala et al., 2014). In the rice-blackgram cropping system, the application of anilophos @ 0.4 kg ha^{-1} at 5 DAT effectively suppressed weed growth and increased grain yield in *kharif* rice as that of hand weeding twice at 20 and 40 DAT and the application of pendimethalin, metolachlor, alachlor each @ 1.5 kg ha^{-1} to blackgram was equally effective in controlling weeds (Reddy et al., 2000).

Rao et al. (2011) found that post-emergence application of quizalofop ethyl @ 50 g ha^{-1} recorded higher seed yield, net monetary returns and BCR of rice fallow black gram cropping system. In lentil, PE application of pendimethalin @ 0.75 kg ha^{-1} fb one hand weeding or imazethapyr @ 25–40 g ha^{-1} either at 25 or 35 DAS improved the grain yield (1662 kg ha^{-1}) (Yadav et al., 2013; Singh et al., 2014). In the rice-lathyrus cropping system early PoE application of imazosulfuron 10% SC @ 100 g a.i. ha^{-1} at 5 DAT in rice is the best weed control method resulting in higher grain yield and B:C in both crops (Pramanick et al., 2014). However, application of almix 20 WP @ 4 g ha^{-1} at 15 DAT also gave good results in the rice-lathyrus cropping system (Dey et al., 2021).

Intercropping enhances crop canopy and thus suppresses weeds. Short-duration legumes, viz. urdbean, mungbean, soybean and cowpea when grown with pigeonpea under an intercropping system suppressed weed flora considerably. The Sorghum+Pigeonpea intercropping system is the most effective weed control cropping system in central and peninsular India. Kaur et al. (2015) reported that the application of PE pendimethalin 1.0 kg ha^{-1} fb PoE application of imazethapyr 0.10 kg ha^{-1} at 30–35 DAS has been found effective weed control method in pigeon pea. Talnikar et al. (2008) reported that PE application of alachlor 2 kg ha^{-1} with HW and hoeing at six weeks after sowing proved most effective and economical in controlling weeds and enhancing the grain yield in pigeon pea + soybean intercropping system.

7. CONCLUSION

Weeds are the most important limiting factors responsible for low yield and hampers crop growth and development. Different rice-based cropping systems have different associated weeds, reduces crop yield and increase disease pest infestation. Therefore, cropping system specific weed management is crucial. An effective cropping system with right crop management, planting, mulching, water management, time of fertilizer application, tillage management etc. not only addresses weed management but also contributes to the overall health and productivity of the agro ecosystem.

8. FUTURE RESEARCH THRUST

Though huge number of research work has already been done in different rice-based cropping systems in different agro climatic zones of the country. The most of the work is confined in the area of different herbicide and mechanical weed control under different crops and cropping systems. Future research work should also focus on special breeding programme for sustainable cultivars of rice and component crops which can suppress the major weeds in different agro climatic zones. Herbicide resistance is one of the important issues which is to be addressed in future. Many new herbicides are coming very fast and their efficacy should be tested under different resource base.

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