

Strategies for integrated weed management in major pulse crops

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Weed compete with crop plant for soil moisture, nutrients, light and space. When improved production technology is adopted the weed management becomes more important so as to improve the efficiency of applied input. Although weed emerge simultaneously with crop plants but due to their better adaption and survival mechanism under adverse condition and also due to their fast growing habit they overpower crop plant. Pulses are cultivated during rabi, kharif and summer season. The weed infestation is more in kharif and summer season crops due to frequent rains and irrigation. Weed problem also vary according to crop, soil type and management practices. Weed competition can cause significant yield reduction in pulse crops. Pulse crops are weak competitors with weeds, therefore planning an effective weed control program is one of the keys to profitable production. Successful weed management requires a field by field approach and requires knowledge of weed diversity and weed seed bank status, soil type, herbicide use history and cropping system.

Keywords: Integrated weed management, Pulse crops

PULSES are grown in northern, central and western India primarily in the summer months (March-June) and in the *kharif* season (June-September), and in the southeastern parts of India in the *rabi* season (November-April). *Kharif* season mung and urd account for about 70% of the total production of these crops. It is, however, noteworthy that *rabi* season cultivation of urd and mung has expanded because of the adoption of improved short-duration (65-80 days) varieties. With the adoption of improved varieties, and because of lower biotic and abiotic stresses in the areas where *rabi* season cultivation takes place, *rabi* crops have seen higher per hectare yields.

Keeping in view large benefits of pulses for human health, the United Nations has proclaimed 2016 as the International Year of Pulses. The International Year of Pulses went a long way to reverse these perceptions and bring to light the crucial roles

that pulses play in healthy diets, sustainable food production and, above all, in food security. Pulses truly are nutritious seeds for a sustainable future, and can make an important contribution to the achievement of many of the Sustainable Development Goals of the 2030 Agenda for Sustainable Development. Between 2001 and 2014, the last year for which data on pulse production are available, the global production of pulses increased by over 20 million tonnes. This increase came about primarily on account of an increase in the production of common bean, chickpea, cowpea and lentil (FAO 2019).

Constraints in pulse production

Over the years, while India has accumulated a huge surplus of wheat and rice, the pulses remain in short supply. Consequently, the per caput availability of pulses has progressively declined from 65.5 g a day in 1961

to merely 39.4 g in 2011 against the minimum requirement of 160 g/capita/day. Considering the anticipated increase in global demand in the future, owing to rising incomes, and growing population on the one hand, and the supply-side constraints like land availability for pulse cultivation, lack of technological breakthrough in pulse varieties and cultivation, resulting in low productivity, on the other. Stagnant production and soaring prices of pigeonpea (red gram) has been a matter of concern in a country like India where this pulse crop is consumed heavily as *dal*. It seems that unless area under pulses expands significantly, or productivity improves appreciably, it would be difficult for the pulses market to see any appreciable growth in the coming years.

To tackle these problems and intensify the research efforts, three Coordinated projects, each for chickpea, pigeonpea and MULLaRP

(mungbean, urdbean, lentil, lathyrus, rajmash and pea), along with one national network research project on arid legumes (guar, moth bean, cow pea and horse gram) was initiated in the country. The government has also implemented the National Food Security Mission (NFSM) on pulses in 622 districts of 27 major pulses growing states of the country. The Pulse Mission, a government scheme over the last five years has incentivized farmers to improve pulses production in the country and enabled more people to consume protein-rich diet. As a result of this, large amount of self-sufficiency has been achieved in the area of major pulses.

While pulses markets have improved in recent year, the complexities of pulse production compared with other crops span from agronomic to other problems like policy matters. In major pulse-producing countries, due to the lack of policy attention by the government, investments attracted by pulses are much fewer than those in cereal and other crops. Other factors that have inhibited the productivity growth are lack of irrigation, low application of fertilizers, climatic conditions, and low remunerative prices to the farmers. Crops under abiotic stress are usually more susceptible to weeds, insects and diseases, which increase the losses considerably. One way to increase the quantity and quality of food is to reduce damages caused by insects, diseases and weeds to crops. Pathogens cause losses in 10-16% of the global harvest. According to an estimate, in India, weeds cause about 33% of the total annual loss of agriculture. If weeds are not managed properly then it can reduce the yield of pulses to the tune of 30-80% in monsoon season and 18-80% during winter and summer season. Therefore, one cannot obtain the full yield potential of any pulse crops, unless the weeds are properly removed from crop field. Among the most important biotic stress faced by cool season food legumes like chickpea, lentil, pea, faba bean, and grasspea in their major production regions in Asia, Africa, and Oceania,

weeds come at third place after diseases (both foliar and root) and insect pests. Some common pulses and their yield loss have been given in Table 1.

Among the various biotic stresses, weeds are the major one which causes severe yield loss in pulses. Due to initial slow growth of pulses, weeds emerge first and gain competitive advantage over the crop and exhibit smothering effect on crop. Knowledge of weed infesting the field is mandatory for deciding weed management options to be used e.g. choice of herbicide is dependent upon type of weed flora which was present in past and expected to emerge in the field for pre-emergence herbicides or is present in the field for post-emergence herbicides. Also, periodic weed survey/surveillance showed that predominance of weeds keep on shifting from one weed to another weed mainly due to adoption of improved agronomic practices like change in cropping systems, better irrigation facilities, fertilizer application, sowing time, crop cultivars and particularly weed management or herbicide use. Therefore, weed survey in any crop gives an insight to the extent of weed problems and knowledge of associated weed composition which helps in devising weed management practices before it takes alarming proportions. Moreover, major area of pulses (84%) are under rainfed condition and grown in combination with non-legume crop. Weeds besides causing direct loss in yield also hinder farm activities and serve as alternate host to many pests. Weed management in pulses is essential to bring the weeds below the threshold level to maximize the seed yield and quality.

Weed flora infesting pulse crops

Intensity of weeds in a pulse crop depends upon agro-ecological conditions and cultural practices followed. These weeds rob the crop of precious nutrients and moisture. The major weeds found infesting *rabi* pulses are *Chenopodium album*, *Fumaria parviflora*, *Lathyrus* spp., *Melilotus alba*, *Vicia sativa*, *Cirsium arvense*, *Rumex dentatus*, *Rumex spinosus*, *Anagallis arvensis*, *Veronica agrestis*, *Medicago denticulata* among broadleaf weeds and *Phalaris minor*, *Avena ludoviciana*, *Poa annua*, *Polypogon monspeliensis* among grasses. During rainy (*kharif*) season, weeds pose a serious problem. The major weeds found infesting *kharif* pulse crops are annual grasses like *Echinochloa colona*, *Dactyloctenium aegyptium*, *Eleusine indica*, *Digitaria sanguinalis*, *Commelina benghalensis*, *Eragrostis* spp.; broadleaf weeds like *Trianthema portulacastrum*, *Digera arvensis*, *Phyllanthus niruri* and perennials like *Cyperus rotundus* etc. During spring/summer, both *rabi* and *kharif* season weeds can infest the crop depending upon growth behavior.

Beside these weeds, parasitic weed such as *Cuscuta* and *Orobanche* has been known to threaten legume crops like faba bean, pea, lentil, vetches, chickpea, grass pea and other grain and forage legumes in the Mediterranean basin, Middle East and Asia since antiquity. Field control of these parasitic weeds is challenging because host and pathogen are both plants and pathogenesis occurs underground

Weed management in pulse crops is of particular importance as these crops are poor competitor because of their slow establishment and limited vegetative growth in initial critical

Table 1. Extent of yield loss due to presence of weeds in pulse crops

Pulse crops	Loss in seed yield (%)	Critical period of crop-weed competition (days after sowing)
Red gram/ Pigeonpea	21-52	15-60
Green gram/ Moongbean	40-50	15-30
Black gram/ Urdbean	44-83	15-30
Rajmash	20-48	-
Chickpea	29-70	30-60
Lentil	70-87	30-60
Fieldpeas	25-35	40-60
Mothbean	30-40	15-60

period of crop-weed competition. Pulse crops normally grow very short except pigeon pea and as a result crop plants can be smothered with dense growth of weeds. Weed infestation in field may reduce yield depending upon intensity, nature and duration of weed competition (Table 1).

Critical period of crop-weed competition

Pulse crops are very sensitive to early weed competition. The competition becomes severe due to smothering effect when weeds emerge earlier than the crop. The critical period of crop-weed competition is an important principal of an integrated weed management (IWM) program. It is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses and weeds that are present before or emerge after this period do not cause significant yield loss. Depending upon crop duration and growth behaviour, critical period

of crop-weed competition varies. First 30-60 days are very critical in life cycle of plants of pigeonpea (red gram), soybean, chickpea, lentil and pea as these are long duration crops and have bunch-type traits. Whereas weed control is required for initial 15-30 days of the crop season of green gram, black gram and cowpeas as these are short duration crops and have branching-type growth traits. Cowpea is used as cover crop in widely spaced cereal crops like maize. Crop competitiveness with weeds depends largely upon rate and extent of crop canopy development; intercepting maximum sunlight and shading the ground and inter-row spaces.

WEED CONTROL APPROACHES

Weeds should be managed in such a way that will encourage the growth of crop plants beneficial to our interests and suppress the remaining

unwanted plants (weeds). Various weed control measures can be adopted to keep the weeds below economic threshold levels are as under:

Preventive methods

For successful weed management, it is most important to prevent the distribution of weed seeds from one field to another, and from infested to uninfested areas. One year's seeding makes seven years' weeding is used figuratively for the danger of allowing weeds to grow and seed themselves. Weed prevention comprises all measures, which checks the entry and establishment of weeds in an area and also includes farm hygiene that prevents the every year production of seeds, tubers and rhizomes by the weed species already present on the farm; preventing the weeds from becoming a problem over time. These methods may be physical, mechanical, chemical or



Fig. 1.a. Chickpea infested with winter season weeds



Fig. 1.b. *Celosia argentea* in pigeonpea



Fig. 1.c. *Asphodelus tenuifolius* in chickpea



Fig. 1.d. *Convolvulus arvensis* in chickpea

quarantine laws which prevent any new weed to infest new habitat. Non-cropped areas like irrigation channels, drainage channels, ditches, fence lines, farm boundaries, bunds and other similar non-cropped areas are often neglected by the farmers. These places act as source of weed infestation to the cropped areas. These areas can be kept free from weeds with the use of contact herbicides or physical methods. Weeds spread to new areas through crop seeds contaminated with weed seeds especially noxious ones. The contamination of crop seeds can be prevented in two ways: by producing weed free crop or by cleaning the crop seeds of weeds before storage and at sowing time. Seed cleaning devices like use of sieves/magnetic separators/velvet rollers/dented plates/salt solution separation can be used to clean crop seed. If there is need of outsourcing of seed, then source of seed should be reliable and certified/truthfully labeled seeds of desired cultivar should be preferred.

Ecological approaches

Weed management differs from weed control or weed eradication wherein weeds are kept under check at a level that these do not cause economic loss of the crop. Weed scenario present within crops is the end consequence of different agronomic and ecological weed management practices. Good weed control practices will be that which can increase weed species diversity, yet maintaining their biomass below a critical threshold level for desired crop growth and yield. There is change in the distribution of weed species in a population or increase in dominance of one or more species within a population. Understanding weed biology and ecology is pre-requisite to develop strategies for the cultural management of any weed. Information of weed biology helps in framing time-chart for different weed control operations; identifying the weakest links in phenology of weed plant so that agronomic interventions can be done to reduce crop-weed competition.

Quantifying weed seeds in soil seed bank is of particular importance

as it determines the potential density, frequency and diversity of weed infestation in particular field. A better understanding of the weed seed bank dynamics is critical for the development of more efficient weed management and to regulate communities of weed species. The longterm goal of integrated weed management strategies is to reduce the size of the weed seed bank in different cropping system. Weeds are uprooted before these set seeds or even flower to avoid further addition to weed seed bank. Broader understanding of the effect of weed control methods on weed population dynamics and ecology will result into effective weed management. Integrated weed management practices keep weeds unsteady and reduces capacity of weeds to become accustomed to a constantly changing system that uses many different control practices.

Soil solarization: Solarization is a method of heating the surface soil by using plastic sheets placed on moist soil to trap the solar radiation. By this method the soil temperature increased to 8-12° C over the corresponding non-mulch soil and thereby most of the annual and perennial weeds belonging to genera *Amaranthus*, *Anagallis*, *Avena*, *Chenopodium*, *Convolvulus*, *Digitaria*, *Eleusine*, *Fumaria*, *Lactuca*, *Phalaris*, *Portulaca*, *Solanum* and *Xanthium* can be effectively controlled by soil solarization. The degree and duration of soil solarization differ from one weed species to another species. Solarization for only 10 days gives complete control of *Phalaris minor* and *Avena ludoviciana*, the most dominant grassy weeds during winter, where as there is a less effect on *Melilotus indica* even after 40 days of solarization. Variability in weed control due to soil solarization is influenced by soil type, temperature, moisture content, vegetative propagules in soil and the film quality.

Stale seed bed technique: One to two flushes of weeds can be destroyed before planting the crop. Stale seedbed practice has been found very effective in reducing infestation of *Cyperus rotundus* in the crop. In

this practice, weeds are allowed to germinate after a light irrigation or rainfall and emerged seedlings are killed either using a non-selective herbicide or tillage operations, preferably herbicide use as it avoid bringing back the buried seeds again on or near the soil surface and later on sow the crop without any further tillage. Stale seed bed technique is time consuming and delay sowing of crop translating into poor yield.

Crop rotation: The long-term weed population dynamics is affected by the choice and sequencing of crops. The key component of weed management in traditional farming was the rotation of different crops with different life cycles. With each crop, certain typical weeds appear which are less serious in some other crops and these weeds increase rapidly if a favorable crop is grown continuously. Crop rotations are effective in controlling crop-associated weeds. Crop rotation with crops requiring different management practices is well known in disrupting the growth cycle of weeds. Adoption of rotation crops, however, will depend on their market prices; yield stability, prevention of weed seed production and subsequent weed seed bank build up.

Cultivars: The differential morphological character of cultivars plays a vital role in crop-weed competition. Generally, tall cultivars along with early vigour, more tillers, inclined leaves, more biomass accumulation at the early crop stage, high leaf area index and specific leaf area during vegetative growth for rapid ground cover by canopy are desirable traits. The effectiveness of competitive cultivars in weed suppression can be increased with agronomic manipulations.

Intercropping: Changing the plant spacing pattern (intercropping, relay cropping etc) and time of sowing might be helpful in providing additional weed control. Intercropping considerably suppress weeds than sole cropping due to increased population density and crop canopy.

Planting method and time: Row arrangement also affect the weed growth by cutting light availability at

the ground level. Narrower row spacing improves the competitiveness of crops with weeds by developing faster canopy cover. Uniform row planting suppress more weeds than the paired row planting mostly due to low spaces in inter row regions. Planting time decide the occurrence and manifestation of weed species. In timely sown chickpea, the weed population at 30 days after sowing is generally high to force manual weeding, whereas in late sown chickpea the build-up of adequate weed flora is only after 45 days.

Optimum plant population: In an agricultural ecosystem, by maintaining narrow row spacing and high seeding rates, the crop provides a more smothering effect on weeds as less space is available for weeds to flourish. With the help of high crop density per unit area, weeds can be suppressed by maintaining the dominant position of crop plants over weeds through a modification in canopy structure. Higher plant population can put pressure on the availability of space for weed growth and make the crop more competitive against weeds. High seeding rate could partly control weeds depending upon the biology of weeds and crop cultivars present in the field. Higher than optimum plant population for getting weed control is often accompanied by more vegetative growth, insect attack and disease infection, reduced reproductive development in indeterminate crops.

Fertilizer application: Manipulation of crop fertilization especially nitrogen is a promising agronomic practice in reducing weed interference in crops. Poorly fed crop is less competitive in nature as compared to weeds. Without weed management, alone crop fertilization is not helpful for getting higher net returns. There should be more emphasis on application of fertilizers as band placement along crop rows at proper time in optimum quantity.

Mechanical method

Tillage serves only as a temporary means of weed control because the soil contains many dormant weed seeds. Ploughing may bury weed seeds at a depth that prevents

germination but may also expose other, from deeper soil layers to surface where conditions are suitable for germination. Thus, it affects weeds through cutting, burial, uprooting and ouster of weeds; moreover, it changes the soil microclimate and alters weed germination, emergence and establishment. Conservation agriculture may promote the germination and emergence of newly shed weed seeds that stay on or near the soil surface, and these germinated weeds can be killed with any contact herbicide and crops can be sown without any tillage operations. With reduced tillage, density of some annual and perennial weeds can increase, so effective weed control practices should be employed to manage weeds successfully. Precision land levelled or regular sloping fields enable appropriate water management which have profound effect on weed growth and bio-efficacy of any applied herbicide. A well levelled field is essential for good weed control.

Physical methods include pulling, digging, disking, ploughing and mowing. In the past, hand weeding was synonymous to weed management due to abundant labour availability, cheaper cost of labour and the nature of agriculture as major occupation. Hand weeding is time consuming and tedious. When weeds are large enough to be gripped, they are pulled out of the soil and discarded. Smaller weeds can be hand-pulled. Early hand weeding is better, since any delay will enable the weeds to absorb nutrients. Hand hoeing is used as a very handy method of weed control, particularly where line-planting is practiced. Hand hoeing is faster than hand weeding and even creeping perennials can be controlled.

Physical removal of weeds includes use of *khurpi*, spade, hand hoe etc. Manual weeding accomplishes the job effectively but it is a time consuming job and it become difficult to control weed in time on a large scale. Moreover, during rainy season, due to continuous rains weed control operations cannot be done on time. In red gram, green gram, black gram, lentil, pea, chickpea and

soybean, two mechanical weedings, one at 25-30 days and another at 45-60 days after sowing give excellent weed control. Hand weeding/interculture with the help of hoe is always better than herbicides because interculture operations improve aeration in the soil. Hand-weeding still occupies more than 40% of the small farmer's time in the least developed countries and this practice does not completely prevent crop losses caused by weeds. The importance of integrated weed management in developing countries is increasing due to labour scarcity.

Biological control

Seed predation by granivore fauna, such as ants and other insects could be used as an important tool in weed management systems where newly produced weed seeds remain on the soil surface, mostly under zero-till systems. Weed seed predators can be encouraged by retaining crop residues in the field as they serve as forage to them. Since no additional cost is required to apply such approaches, these environmentally-friendly, safe and economical approaches for weed control can be combined with existing practices as a component of an IWM package and potential of biocontrol agents have to be harnessed however, there is very low abundance of these natural enemies at the particular time required to control the weed in a specific agricultural situation.

Chemical approaches

The importance of herbicide use is closely related to the cost and availability of labour. Herbicides are one of the first labour saving technologies to be adopted and proved to be superior weed control and are more energy- and labour-efficient than manual or mechanical methods of weed management. Chemical weed control tactics play a significant role in modern weed management and maintaining productivity of diverse cropping systems, reducing yield losses and facilitating conservation tillage systems. But, repeated herbicide use may result into weed flora shift towards more persistent perennials

Table 2. Commonly recommended herbicides in various pulses

Herbicide (kg a.i./ha)	Time of application	Crops	Weed Control
Fluchloralin 0.75-1.0	Pre-plant	Bengal gram, Lentil, Peas, Red gram, Green gram, Black gram, Cowpeas, Soybean	Annual grasses and some BLWs
Methabenzthiauron 1.75	Pre-emergence	Bengal gram, Lentil, Peas	
Alachlor 1.5-2.5		Red gram	
Pendimethalin 0.6-0.75		Green gram, Black gram, Cowpeas, Soybean, Rajmash	
Nitrofen 1.5-2.0		Green gram, Black gram, Soybean	
Metolachlor 1.0-1.5		Chickpea, lentil, fieldpeas	
Metribuzin 0.25		Fieldpeas	Broad spectrum weeds
Oxadiazon 0.25		Green gram, Black gram, red gram	
Oxyfluorfen 0.1-0.125		Fieldpeas	
Pendimethalin + imazethapyr 0.8-1.0		Green gram, Black gram, Soybean	
Imazethapyr 0.06-0.08	Pre and Post emergence spray	Green gram, Black gram, Soybean	
Imazethapyr + imazamox 0.05-0.06		Green gram, Black gram, Soybean	
Quizalofop-p-ethyl 0.04	Post-emergence	Chickpea, Soybean	Annual grasses
Fenoxaprop		Green gram, Black gram, Soybean	
Clodinafop 0.060		Chickpea, lentil, fieldpeas	

and buildup of herbicide residues in the soil, underground water and consumable products. Non-selective herbicides such as paraquat are sometimes used before establishing pulse crop in zero tillage. Pre-emergence herbicides are applied to the soil within two days of sowing and control weeds before they emerge, while post-emergence are applied to weeds after they emerge. There is a need to use mixtures of different compatible herbicides or sequential spray of pre-emergence application followed by post-emergence herbicides is required for effective weed management. There is one caution that using chemical spray may have adverse effects on human health and the environment, including beneficial organisms and may lead to the development of chemical-resistant insects and weeds. The development of pulse varieties with new and or multiple herbicide tolerances will enable greater variation in herbicide usage patterns and will reduce the risk of herbicide-resistant weed development. The commonly recommended herbicides in various pulses are given in Table 2.

Integrated approaches

Integration of weed control methods is very important for solving long term weed problems. The escaped weed plants after the use of herbicide must be uprooted before

seed setting. These escaped plants may be of resistant population or may be due to lack of proper spraying technology. So, left over plants should not be allowed to form seeds to reduce seed bank. The objective of integrated weed management is to maintain weed densities at manageable levels, preventing weed shifts to more difficult-to-control ones and managing weed biodiversity and puts greater emphasis on preventing weed reproduction, establishment and minimizing weed competition with the crop. It involves the concept of multiple tactics of weed management to maintain weed population below certain level while conserving environment quality and emphasizes on integration of techniques and knowledge in a manner that deliberates to the causes of weed infestation rather than retorting to problems after they occur.

Integration of different methods have synergistic weed management as efficiency of applied herbicides and crop competitiveness against weeds can be improved by integration of improved production and protection practices, their timeliness, optimum fertilization and water management and incorporation of crop residues in the soil. None of these techniques when employed individually result in complete control but the integration of these tools in suitable

combinations works efficiently. Reducing the reliance on one or two specific weed control techniques or tools are helpful in enhancing life of those methods for future use. The inclusion of herbicides with various non-monetary, low-input, low-cost resource conservation techniques like zero tillage, change in establishment methods, line sowing, FIRB sowing, good water and fertilizer management, soil solarization, stale seed bed, crop residue incorporation, mulching, timeliness of operations and other cultural methods could be the component of integrated weed management and are being practised in recent years to reduce herbicide load on ecosystem. Site-specific IWM strategies have to be evaluated considering available resources situation and hydrology/environment in which rice is being grown.

Recommended integrated weed management (IWM) options for pulses

- Pre-emergence herbicides (e.g., pendimethalin 1.0 kg/ha; oxyfluorfen 0.18 kg/ha) + residue retention after pre-em. herbicide application- Controls broad-spectrum of weeds in most pulses.
- Pre-emergence herbicides (e.g., pendimethalin 1.0 kg/ha) – Hand weeding at 30-35 DAS; Controls broad-spectrum of weeds in most pulses
- Intercropping + pre-emergence

herbicides (e.g., pendimethalin 1.0 kg/ha) + residue retention after pre-emergence herbicide application; Controls broad-spectrum of weeds (Pigeonpea + Mung bean, Pigeonpea + Cowpea)

- Raised bed planting + pre-emergence (pendimethalin 1.0 kg/ha) + post-em. (quizalofop-ethyl 50 g/ha) with or without residue (Pigeonpea)
- Zero-tillage with residue + Pre-emergence herbicides (e.g., pendimethalin 1.0 kg/ha) – Controls broad-spectrum of weeds (Summer mungbean, Urdbean)

SUMMARY

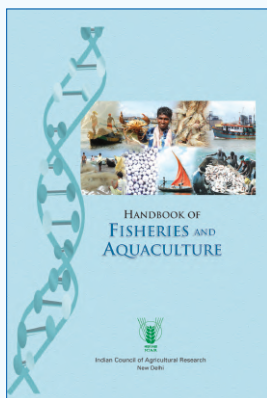
Sustained efforts must be made to improve productivity of pulses in different production systems through available approaches. Suitable and safe

herbicides are limited in pulses, especially for the post-emergent control of broadleaf weeds, with many registered herbicides having a narrow crop safety margin. While cultural practices are at the backbone of an integrated weed management plan, they alone may not be enough to secure adequate weed control and chemical control measures are required for timely management. Including crop rotation in conservation agriculture is a successful approach to reduce weed pressure. There is a need to evaluate the effect of high seeding rates on weed management and crop productivity in areas where herbicide use is limited as in organic production systems or herbicides are less effective. To maximize the effectiveness of any weed management practice and avoid yield reduction, it is important to target the proper crop and weed

growth stage. Integrated weed management has potential to achieve higher productivity and profitability through efficient utilization of resources and better weed suppression. Studies highlight an integration of herbicide, mechanical/manual and/or cultural options that could be profitable in most pulses and pulse-based cropping system through controlling weeds. However, it is crop-specific, location-specific and environment-dependent. Therefore, efficient IWM modules/schedules should be studied across pulses, and pulses-based cropping systems for different agro-climatic regions of the country for efficient management of weeds.

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HANDBOOK OF FISHERIES AND AQUACULTURE



Fisheries is a sunrise sector with varied resources and potentials. The sector engages 14 million people at the primary level and is earning over ₹10,000 crore annually through exports. Fish consumption has shown a continuous increasing trend assuming greater importance in the context of 'Health Foods'. It is expected that the fish requirement by 2025 would be of the order of 16 million tonnes, of which at least 12 million tonnes would need to come from the inland sector and aquaculture is expected to provide over 10 million tonnes. The domestic market for fish and fishery products is also growing rapidly and necessary models and quality control protocols in this regard need to be developed.

In 2006, the Indian Council of Agricultural Research, brought out the First Edition of 'Handbook of Fisheries and Aquaculture'. The present revised edition comprises 42 updated and six new chapters, viz. Fish physiology; Aquaculture engineering, Fisheries development in India; Fisheries cooperatives; Demand and supply of fish; and Climate change – impact and mitigation. The Handbook would be of great value to students, researchers, planners, farmers, young entrepreneurs and all stakeholders in fisheries and aquaculture.

TECHNICAL SPECIFICATIONS

Size : Royal Octavo (16 cm × 24 cm) • No. of pages : i-x + 1116 • Price : ₹ 1500 • Postage : ₹ 100
ISBN No. : 978-81-7164-106-2

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