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Effect of Weeds and Weed Management in Pulses: A Review

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Abstract

Pulses are important for the nutritional security point of view of the cereal based vegetarian diet of large scale of country. India is the largest producer, consumer and importer of pulses in the world. It has been projected that 32 million tonnes of total pulse requirement for the burgeoning population of India, which will grow to 1.69 billion by 2050. To attain up to this level an annual growth rate of 2.2% is required. The demand for pulses continues to grow at 2.8% per annum. Although challenges are diverse including climate changing scenario, decreasing land and water resources, this target is not unattainable. Increasing the average productivity of pulses to > 1200 kg ha^{-1} and bringing an additional area of about 3.5 million ha. Under pulses cultivation will be a concrete step in this direction. Enhancement of yield through development of input responsive varieties with multiple resistances to diseases and insect-pests, short duration varieties that fit well in different cropping systems and climate resilient varieties of pulses will be enormously helpful in a vertical expansion of pulses in the country. Similarly, development of new plant types for different agro-climatic situations, and development of photo-thermo insensitive cultivars in crops like filed pea, urdbean and moongbean will help expanding the areas of these crops in the non-traditional areas of the country.

As a result, pulses are subjected to various types of biotic and abiotic stresses. 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. The literature regarding the importance of weed management in pulses, weed flora, critical period of crop weed competition and different weed management methods of weed control are collected and presented in this paper. Weeds are the predominant biological constraint in pulse production due to the slow initial growth of the crop. Strategies' of weed management depends on the weed competition, types of weeds present and weed control method adopted. In general, critical period of weed competition for short duration pulses is up to 30 days and for long duration pulse crops it is up to 60 days. The major three types of weeds viz., grasses, broad leaved weeds and sedges were found in association with pulses. Intensity of weed infestation varies with agro-ecological conditions and crop management practices followed. A system approach is necessary to maintain the weed population below the economic threshold level thereby reducing the yield loss. Integrated weed management (IWM) which has been proved to be more effective than any single method in alleviating the buildup of weeds in pulse crop.

Key words:- Cultural method, Mechanical method, Biological method, Biotechnological method, Chemical method, Critical period of weed control and herbicide resistant.

Introduction

Crops grown for human consumption is at risk due to the incidence of pest's *viz.*, weeds, insects and diseases. Among the different pests causing yield loss, weeds are the severe and predominant one. The loss occurred by weeds exceeds the total loss caused by different group of pests in agriculture. In India, the percentage loss caused by weeds, insects, diseases and others are 37, 29, 22 and others 12, respectively[64]. However, in the world, the percentage loss caused by weeds, insects, diseases and other pests accounts for 45, 30, 20 and 5 per cent,

respectively[27]. Monetary loss caused by weeds in India was 11b$. The highest monetary loss was reported in rice (4.4b$) followed by wheat (3.3b$). Among the pulses the highest loss was reported in soybean (1.5b$) which was followed by green gram (0.16 b$)[19].

Importance of Weed Management In Pulses

Pulses are the important crop after cereals and are the cheapest source of dietary protein. In India area under pulses was 25.2 m ha, the production and productivity were 23.5 mt and 764 kg ha^{-1}, respectively[29]. According to Indian Council of Medical Research, the per capita consumption of pulses was declined from 67 g day^{-1} $person^{-1}$ during 1951 to 35 g day^{-1} $person^{-1}$ during 2010 as against the recommendation of 65 g day^{-1} $person^{-1}$. After the Green revolution, due to various biotic and abiotic stresses the production of pulses remains stagnant over the years. 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. Moreover, major areas of pulses (84 per cent) are under rainfed condition and grown in combination with non-legume crop. As a result, pulses are subjected to various types of biotic and abiotic stresses. 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. It has been estimated that loss caused by weeds was greater than the loss caused by other pests. About 31 to 110 per cent yield improvement can be achieved in *Kharif* pulses like pigeon pea, urd bean and mung bean compared to control[2].

The yield reduction owing to weed infestation varied with the crop, weed density, crop management and agro-climatic conditions. From the results of multi-location study, Yield reduction due to weeds in pigeon pea was (46.7%), urd bean (55.4%), chickpea (48.1%), lentil (58.8%) and field bean (47.1%)[64]. The yield loss reported in mung bean was 38.6 per cent, rajma (49.5%), lathyrus (46.1%) and moth bean (30.4%)[7, 27, 29, 42]. Weeds also removed substantial amount of nutrients from the soil. The nutrient removal was directly related to weed intensity. Weeds removed about 26.89, 4.11 and 23.94 kg ha^{-1} of N, P and K and also observed that weeding significantly increased the nutrient uptake by pigeon pea[43].

Strategies for Weed Management in Pulses

To develop a successful weed management strategy, it is necessary to understand the biology and ecology of the weed flora, understand the period of crop weed competition and have an idea about the weed management methods. The selection of suitable weed management method depends on environmental concerns, desired management intensity, labour availability, weed pressure and crop. In general, for short duration pulses the critical period of crop weed competition is up to 30 DAS and for long duration pulses it is up to 60 DAS[29].

Critical Period of Weed Control

The critical period of weed control (CPWC) is the period during which the crop must be kept weed free to prevent yield loss due to weed infestation[59]. The potential yield of crops can be maximized if the weeds are controlled during the

critical period of crop weed competition [34, 58]. For producing optimum yield, the annual crop requires a weed free condition for the first one fourth to one third of their growing period. In general, critical period of crop weed competition of short duration pulses like urd bean and mung bean is up to 30 days and for long duration crops like pigeon pea, chickpea and French bean, it is up to 60 days. Critical period of weed control depends on the crop/cultivar, weed flora, weed intensity and climatic and edaphic condition. Among the sedges, Cyperus rotundus infestation poses severe threat to summer pulses[18]. Rainfed chick pea and lentil, *Asphodelus tenuifolius* L. causes serious problem in northern and central India. *Trianthema portulacastrum* L., *Trianthema monogyna* L. is the major broad leaf weed causing yield loss in semi-arid tracts and Indo Gangetic plains[26]. However, in light textured soils of northern and Bundelkhand region and heavy soils of central and southern parts of the country, *Celosia argentea* L. is the major weed causing yield loss[29]. The critical period of crop weed competition and losses in yield of different pulses due to weed infestation are given in Table 1.

Table1 Critical period of crop weed competition in pulses

Crop	Critical crop period (DAS)	Reduction in yield (%)
Pigeon pea	15-60	24-40
Green gram	15-30	30-50
Black gram	15-30	30-50
Chickpea	30-60	15-35
Lentil	30-60	20-30
Pea	30-45	20-30
Source: (DWSR, 2018).		

Weed Flora of Pulses

Weed flora in pulses varies with agro-ecological conditions and crop management practices followed. Grasses, broad leaved weeds and sedges were found in association with pulses. The common broad leaved weeds found along with pulses are *Celosia argentea, Cleome viscosa, Commelina benghalensis, Cucumis trigonus, Digera arvensis, Eclipta alba, Euphorbia hirta, Phyllanthus niruri, Trianthema monogyna, Convolvulus arvensis. Ageratum conyzoides, Anagallis arvensis, Argemone mexicana, Asphodelus tenuifolius, Carthamus oxyacanthus, Chenopodium album, Coronopus didymus, Fumaria parviflora, Gnaphalium indicum, Lathyrus aphaca, Launaea nudicaulis, Medicago denticulata, Melilotus alba, Rumex dentatus, Solanum nigrum, Spergula arvensis, Vicia hirsuta, Vicia sativa, Amaranthus viridis, Physalis minima, Solanum nigrum and Trianthema monogyna.*

The grassy weeds found in pulse fields are *Echinochloa colonum, Cynodon dactylon, Eleusine indica, Dactyloctenium aegypticum, Digitaria sanguinalis, Echinochloa crusgalli, Setaria glauca, Saccharum spontaneum, Sorghum halepense, Eragrostis tenella, Avena ludoviciana, Phalaris minor, Lolium temulentum, Poa annua, Polypogon monspeliensis.* Compared to broad leaved weeds and grasses, a few sedges are present in the pulse fields. The predominant ones are *Cyperus difformis, Cyperus iria* and *Cyperus rotundus*[46].

Integrated Weed Management

Integrated weed management (IWM) is an efficient tool to shift crop weed competition in favour of crop by adopting chemical, cultural, mechanical and biological methods of weed control. Integrated weed management has been proved to be more effective than any single method in alleviating the buildup of weeds in a crop land[31]. It is a system approach to maintain the weed population below the economic threshold level by employing all available means of weed control in coordination[41]. It includes cultural, mechanical, chemical, biological and biotechnological practices.

Cultural Methods

It is reported that cultural methods play an important role in improving the crop health and competitive[16, 37] ability of crop for both the above and below ground resources and enables the crop to survive under existing weed pressure. Different cultural methods are:

Optimum time of sowing

Density and dry matter of weeds can be significantly reduced by adopting optimum time of sowing. The delay in sowing from May to June the weed density and biomass of weeds increased significantly. May sown crop recorded higher yield than June sown crop. Hence, the optimum time of sowing for pigeon pea would be 10-25th May. Higher yield recorded in May sown crop might be due to less competition for the resources by the weeds and better *vigour* of the crop[33].

Method of planting and sowing

The germination and growth of weeds will be different under different planting methods. Hence selection of suitable planting method helps to eliminate weeds to a certain extent. Flat method of planting recorded significantly lower density and dry weight of weeds and 14 per cent yield enhancement in chick pea. Wider spacing in ridge sowing intercept more solar radiation which will stimulate the vigorous growth of weeds resulted in higher weed density and biomass[6].

Crop rotation

Crop rotation is an important tool for weed management in pulses. It affects the demography of weeds and subsequent population dynamics[29,32] and crop rotation breaks the weed seed cycle and prevents the development of diverse weed population. Parasitic weeds in pulses *viz., Striga hermonthica / asiatica, Orobanche ramosa, Cuscuta spp.* can be effectively controlled by adopting crop rotation with cereals[24]. Growing sesame in rainy season significantly reduces the population of *Cyperus* in winter pulses. Similarly, rice in rotation, reduces the density of *Cyperus rotundus, Phalaris minor* and *Chenopodium album* in chickpea and fieldpea[29].

Intercropping

Intercropping found to suppress the weeds through the formation of good crop cover. An inclusion of short duration quick growing crops in between the inter row spaces of long duration tall growing crops suppress the weeds and resulted in significant reduction in cost of weeding[1]. Due to slow initial growth and wider spacing, weed infestation was severe in pigeon pea[10]. It was revealed that if weeds were not controlled up to harvest 79.9 per cent yield reduction was observed in pigeon pea. However, soybean was intercropped with pigeon pea, the yield

reduction was recorded only 38.2 per cent[57]. Studies conducted by Indian Institute of Pulses Research, Kanpur revealed that intercropping with cowpea, urdbean and mungbean suppress the weed flora by 30 to 40 per cent in pigeon pea[18]. Cowpea intercropped with pigeon pea recorded the lowest density and dry weight of weeds compared to pigeon pea intercropped with green gram and black gram and recorded the highest yield. The smothering effects of intercrops have positive effect on *vigour* and growth of pigeon pea which ultimately enhances the dry matter production and yield[47].

Soil Solarization

Soil solarization is an environment friendly cultural practice involves covering the moist soil surface with a polyethene sheet (LDPE film) of 25 to 50 mm size to prevent the solar radiation falling on the ground. This will raise the soil temperature inside the polythene sheet and will kill fungi, nematodes, weed seeds and weeds. Soil solarization technique is found best on heavy soil compared to light soil, since heavy soil hold more water and produce enough steam every day. In addition to have weed control effect, the other beneficial effect includes, improves the structure of soil, increase the availability of nutrients especially N and control of soil borne fungi (*Fusarium sp.*) and root knot nematodes. Due to soil solarization, soil temperature was increased to C compared to non-mulched soil. Weeds belongso 8 to 10 to the genera, *Amaranthus, Anagallis, Avena, Chenopodium, Convolvulus, Digitaria, Eleusine, Fumaria, Lactuca, Phalaris, Portulaca, Solanum* and *Xanthium* were effectively controlled. However, weeds having underground rhizomes (*Cynodon dactylon*), underground tubers (*Cyperus rotundus*) and hard seed coat (*Melilotus spp.*) were not controlled (Patel *et al.,* 2005). The effect of soil solarization diminishes with soil depth and hence the viable weed seeds present in deeper soil layers survive. Broad leaved weeds were more effectively controlled[40]. Soil solarization with black polyethene film sheet significantly reduced the weed density and dry weight compared to control in soybean crop. Compared to 15 days, 30 days soil solarization was found better in reducing the density and dry weight of weeds and a yield enhancement of 11.5 per cent were observed[51].

Mulching

Mulching the crop field with suitable material will reduce the weed seed germination. Natural organic material as well as plastic sheets can be used as mulch. Study conducted in the past pointed out that l kg m^{-2} of organic mulch to a thickness of 10 to 15 cm was sufficient to cover the soil and resulted in significant reduction in the population of weeds and increase in yield. Mulches help in weed control by inhibiting the weed seed germination, smothering weeds and favours the crop growth by reducing the evaporation loss of soil moisture and maintaining the soil temperature[4]. Both annuals and as well as perennial weeds were effectively controlled by mulching[21]. Mulching significantly reduced the density and dry weight of grasses, broad leaved weeds and sedges in green gram. Compared to straw mulching, dust mulching was found more effective in reducing the weed density and dry weight and recorded the highest net returns of Rs. 80,830 ha^{-1}[60].

Stale Seed Bed

Stale seed bed is based on the principle that germinal weed seeds are flushed out prior to the planting of the crop, so that weed seed bank in the top soil layer is depleted and subsequently reducing the weed seed emergence[20]. Method of killing emerged weeds and duration of stale seed bed determines the success of stale seed bed[14]. Stale seed bed significantly reduced the viability of weed seeds like *Digitaria sanguinalis, Poa annua* and *Eleusine indica* in the top two cm soil layer[54]. Stale seed bed will be successful when most of the weeds are present in the uppermost 5 cm of soil profile[44]. Stale seed bed reduced the weed population by 53 per cent compared with the treatments in which this practice was not adopted[50]. Stale seed bed followed by one hand weeding recorded the highest gross margin in organic garden pea[15]. Weed species that requires light to germinate, low dormancy and present in the topmost soil layer (3-5 cm) are more sensitive to seed bed technique[9].

Mechanical Method

Mechanical method involves the removal of weeds with the help of various tools and implements. Hand operated/ power operated/ animal drawn harrows /cultivator and manual or power operated weeders are the commonly used ones. Tillage and hoeing come under mechanical method.

Hoeing

Young *et al.,* (2014) revealed that hoeing is the removal of weeds either by uprooting or plucking with a hand operated implements or animal drawn implements. It involves the use of tillage implements like harrows (Blade harrow), weeders (Balram weeder, wheel hoe weeder) and cultivators driven by animals or power operated. Both annual as well as perennial weeds can be effectively controlled by hoeing.

Research results revealed that one or two hoeing at the critical stages of pulses provide satisfactory weed control. Since it involves labour, the success of this method depends on the labour availability at the critical stages of the crop[45]. Hand hoeing at 25 and 40 DAS recorded the lowest density and dry weight of weeds and registered 44.22 per cent yield enhancement over control in green gram[24].

Tillage

Tillage is one of the major weed control method followed by the farmers for several decades. Tillage controls the weeds by altering the soil environment, burying the weed seeds deep enough to prevent their emergence, uprooting, encouraging and preventing the weed seed germination and establishment due to the vertical and horizontal movement of seeds[38, 56]. Stated that vital factor for the success of no till crop production is weed control and it largely depends on the proper usage of herbicides. Zero tillage recorded lower density and dry weight of weeds and registered higher yield in mung bean compared to conventional tillage due to the prevention of weed seeds reaching the surface of the soil and resulting lesser emergence of weeds[49].

Chemical Method

Chemical weed control is the cheapest and economically feasible option for weed control in pulses due to very high efficacy, very large coverage, ease in application, useful in areas where labor is scarce/costly and intercultural operations

is not possible. It reduces the cost of pre-planting tillage, kills the weeds in situ without the dissemination of vegetative propagules and effectively controls brush weeds and perennials. Chemical method of weed control increased the yield of pulses by 10 to 50 per cent. For the best results herbicides should be integrated with other methods and cannot be considered as an alternative to other weed control methods.

The efficacy of herbicides depends on the right selection of herbicide, method of application and application at recommended dose. Based on the time of application, herbicides used in pulses were classified in to pre and post emergence herbicides. The commonly used pre emergence and post emergence herbicides are shown in Table 2[6].

Table2 Pre-emergence and post emergence herbicides commonly used in pulses.

Herbicide	Herbicide group	Dose (kg ha^{-1})
Pendimethalin	Dinitroaniline	0.75-1.20
Imazethapyr	Imidazolinones	0.075-0.150
Oxyfluorfen	Ethers	0.1-0.15
Diclosulam	Sulfonylureas	0.037-Soya bean 0.017-Mung bean
Quizalofop-p-ethyl	Aryloxyphenoxy propanoic acid	0.0375-0.050
Haloxyfop-p-methy	Aryloxyphenoxy propanoic acid	0.075-125
Imazethapyr	Imidazolinones	0.05-0.075

Stunting and swollen root tips are the common symptoms. Imazethapyr can be used as both soil and foliar herbicide. Absorption by root and foliage and translocate through both xylem and phloem. It inhibits the enzyme acetolactate synthase, the enzyme accelerated the biosynthesis of branched chain amino acids, valine, leucine and isoleucine. Symptoms are stunting, interveinal chlorosis, purpling and gradual death of plants. Oxyfluorfen enter into leaves, stems and roots and caused cell membrane damage. Necrosis of leaves and stem are the major symptoms observed. Diclosulam is also an ALS inhibitor absorbed both through roots and foliage.

The commonly used post emergence herbicides are Imazethapyr an ALS inhibitor and quizalofop-p-ethyl and haloxyfop-methyl, both are ACCase inhibitor. These herbicides absorbed through foliage and translocated through phloem to the growing point and inhibit the meristematic activity. These herbicides inhibit the acetyl CoA-carboxylase (ACCase) enzyme which plays a major role in fat metabolism. Chlorosis of the newly formed leaves and reddening and purpling of the older leaves are the common symptoms. The growing point becomes brown, necrotic and eventually rotted.

Pendimethalin controls the initial flush of monocotyledonous weeds and some dicotyledonous weeds in pulses[25]. Pre emergence application of pendimethalin followed by manual weeding at 25 to 30 DAS was commonly recommended for weed control in mung bean[48]. The pre emergence application of Imazethapyr@ 100 g ha^{-1} can be recommended as a better weed management practice for higher yield in mung bean[3,28].

The results revealed that ACCase inhibiting herbicides had significant effect in reducing the density and dry weight of

weeds and recorded higher yield than that of control and hand weeding treatment. In another study, it was observed that quizalofop-p-ethyl was very effective in reducing the grassy weeds in black gram[35].

Herbicide Resistance

Herbicide resistance is defined as the genetic capability of a weed population to survive a herbicide application that is normally fatal to majority of the individuals of that species. The major reason for herbicide resistance in weeds is due to the application of same herbicide in the field year after year.

Overcome herbicide resistance

Herbicide resistance can be overcome by the use of herbicide mixtures and following herbicide rotation. Herbicide mixtures containing herbicides with different mode of action which will prevent the possibility of target site resistance in susceptible species[39]. The advantages of herbicide mixtures are, it reduces the herbicide load in environment, improve the weed control efficiency and reduces the cost of cultivation. Imazethapyr 2% + pendimethalin 30% EC is the one pre-mix herbicide mixture, containing two herbicides with different mode of action available in the market for weed control in pulses. Pre-emergence application of pendimethalin @ 1000 g ha^{-1} or premix combination of imazethapyr + pendimethalin at doses, 800, 900 and 1000 g ha^{-1} were found more effective for weed control in black gram. Among the three doses, the higher doses (900 and 1000 g ha^{-1}) were found more effective in reducing the density and dry weight of weeds and recorded higher weed control efficiency and yield[53].

The practice of following systematic, rotational sequence of herbicide in the same field[36] is called herbicide rotation[17]. Post emergence application of imazethapyr in first year, second year pre emergence application of pendimethalin fb quizalofop-p-ethyl. The herbicide rotation will delay the target site resistance in weeds[8].

Biological Method

Biological method of weed control was reported in the management of *Parthenium*, an invasive alien weed found in pulse growing areas especially in chickpea[36]. Germination and growth of legumes were found to be more affected than cereals due to *Parthenium.* *Zygogramma bicolorata* was the only successful insect bioagent against Parthenium, he has also reported that *Zygogramma bicolorata* alone is not sufficient to control Parthenium, since the beetle is able to multiply only during the rainy season[55].

Biotechnological Method of Weed Control

Biotechnological tools that can contribute in weed management are herbicide resistant crops. Herbicide resistance crop is the capacity of a crop, to tolerate particular herbicide at greater dose than the wild type of that crop or weeds. Herbicide resistant crops are developed either by inserting a foreign gene (transgene) from another organism into a crop or by regenerating herbicide tolerance from existing crop germplasm[30].

Conclusion

Weeds cause complete crop failure of pulses if not checked at the early stages. Dependence on any single method of weed control will not provide satisfactory weed control. Economically feasible management techniques should be

integrated to keep the weed population below the threshold level to enhance the crop productivity. Though herbicides knock down the weeds suddenly, it should be integrated with other methods especially cultural methods, since the weeds differ in dormancy and growth habit. Continuous application of single herbicide will lead to development of resistance in weeds. Herbicide rotation or use of herbicide mixtures will delay the development of resistance in weeds. The main objective of weed management programme is to deplete the weed seed bank and allow the crop to be more competitive either by delaying the emergence or suppressing the weed seed emergence and weed growth, since weeds are only the symptom the real problem is the weed seed bank.

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