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Weed Management in Summer Sown Blackgram (*Vigna mungo* L.) through Sequential Application of Pre and Post-emergence Herbicides: A Review

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ABSTRACT

Blackgram is one of the most important pulse crop cultivated in India. It is a rich source of protein, carbohydrate, fat, amino acids and vitamins as human food and also serves as highly nutritive livestock feed. Despite of having multiple benefits poor agronomic and management practices *viz.,* use of poor-quality seeds, poor crop establishment, moisture stress at critical stages of crop growth, low fertilizer input and inadequate weed management are responsible for low productivity of blackgram. Out of these poor weed management is one of the most important factors that needs focus of ongoing research and researchers to cut down the yield losses in blackgram. Weeds are the major biological constraint that leads to decline in crop yields. If not controlled in the early crop growth stage, they can reduce the yield up to 27-78 per cent. There are numerous weed control methods like cultural, physical/ mechanical, biological and chemical available by which we can successfully controlled weeds. Out of these, the chemical weed control method is the most efficient way to control them by sequential application of pre-emergence and post-emergence herbicides in summer sown blackgram. Due to the availability of several herbicide molecules (chemical) in the market, its easy and very effective way to control weeds when applied in the right amount at the right time. Several weed scientists also suggest that allelopathy can be used to control and may offer substitute to chemical weed control or may lead to reduction in dose of herbicides applied. So, it can also be said that the integrated weed management method is the key to sustainable crop production worldwide and will continue to be the main pillar for weed control in blackgram. The present review paper is focussed on to get a clear understanding of the chemical method of weed control in black gram and has been undertaken to study the efficacy of pre-emergence application of herbicides followed by post-emergence application of herbicides in summer blackgram.

Key words: Allelochemicals, Blackgram, Herbicides, Super-weed, Weed management.

Blackgram (*Vigna mungo* L.) also known as urdbean (2n=22), is the 3rd most important pulse crop in India after chickpea and pigeonpea, which is grown in various agroecological conditions and season under diverse cropping system. Blackgram is an important self-pollinating diploid grain legume crop belonging to family *leguminosae* and nutritionally rich in protein (25-26%), carbohydrates (60%), fat (1.5%), minerals and essential vitamins, which are almost three times than that of cereals (Shweta *et al*., 2017). It is also rich in essential amino acids such as arginine, leucine, lysine, isoleucine, valine and phenylalanine, which complements to cereal based diet. In addition to being an important source of human food and animal feed, it also plays an important role in sustaining soil fertility by improving soil physical properties and fixing atmospheric nitrogen. In India, blackgram is grown in an area of 32.48 lakh hectares with the production and productivity of 21.99 lakh tonnes and 604 kg/ha, respectively during 2014-15 (Economic Survey, 2014-15). In Bihar, the crop covers an area of 15503 hectares with total production of 14142 tonnes and productivity of 879 kg/ha (http://www.atarikolkata.org/wp-content/uploads/2018/10/Enhancing-pulse-productivity-through-agro-technologies.pdf). The maximum area under black gram production is in the districts of Katihar, Khagaria, followed by Lakhisarai and Bhagalpur. It is mostly cultivated as *kharif* crop and is suitable as rice fallows and intercrops. It can be cultivated on varied range of soil from loam to heavy clay but the ideal soil is well drained soil with pH ranging between 6-8.

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There is various reasons for low yields in black gram, lack of proper seed treatment, proper fertilizer input, lack of proper tillage and field preparation, lack of disease tolerant varieties for mosaic *etc*., lack of proper weed management practices and integrated pest control methods. Out of these weeds remains the major biological constraint in increasing crop productivity of blackgram. The most prominent weed species that affects the crop are, namely, *Trianthema monogyna*, *Sorghum halepense*, *Cyperus rotundus*, *Amarathus viridis*, *Celosia argentea*, *Chenopodium album*, *Cleome viscosa*, *Commelina nudiflora*, *Cucumistrigonus*, *Euphorbia hirta*, *Phyllanthus niruri*, *Eclipta alba*, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Physalis minima* and *Commelina benghalensis etc.* during spring/summer and monsoon season (Kumar, 1999). The weed are major nuisance and pose competition to the crop for essential growth factors *viz*., nutrients, space, light and moisture during early phase of growth and leads to a decline in yield by 27 to 78 per cent depending upon the severity of weed infestation (Gogoi *et al*., 1992; Prajapati *et al*., 2018). Hand weeding is the commonly practiced process to control weeds in this crop (Chand *et al*., 2004). It is laborious, time consuming, costly and tedious. Moreover, weather conditions in Kharif do not permit timely hand weeding due to wet fields as a result of rains (Prajapati *et al*., 2018). However, different types of weed control methods such as cultural, physical/ mechanical, biological and chemical management practices have been successfully deployed to control weeds. Out of these, the chemical method of weed control by pre-emergence and post-emergence application of herbicide or combinations of both is the most effective way to control weeds in the first few weeks once the crop are sown. According to Kumar and Tewari (2004), the application of pre and post-emergence herbicides offer an alternative for effective weed management in blackgram in alluvial soils as seen in Kanpur, Uttar Pradesh. It is also suggested by several weed scientists that allelopathy can be used to control and may offer substitute for chemical control or may lead to reduction in dose of herbicides applied. Thus, it can be said that integrated weed management remains the key to sustainable crop production worldwide and will also continue to be the main pillar for weed control in blackgram. Keeping the previous studies in mind,an attempt has been made in the present review paper to study the efficacy of pre-emergence application of metolachlor and pendimethalin followed by post-emergence application of fluazifop-p-butyl in summer blackgram.

Weed and its deleterious impact on agricultural crops

Weeds (terrestrial, parasitic and aquatic) interfere with crops cultivation and ecosystem resilience in addition to loss of biodiversity, potentially productive land, grazing land and livestock production. They also cause poisoning of humans and livestock, erosion following fires in heavily invaded areas, choking of navigational and irrigation canals and reduction of available water in water bodies (Singh, 2004). The associated ecological factors influence the impact or losses caused by weeds in different ecosystems. Abundant information is available in India on weeds in rice (Rao *et al*., 2010; Subudhi *et al*., 2015), in wheat (Punia *et al*., 2017), cotton (Nalini *et al*., 2015), sugarcane (Jeyaraman *et al*., 2002), groundnut (Rajendran and Lourduraj, 1999), soybean (Panneerselvam and Lourduraj, 2000), forests (Meher-Homji, 2005), road sides (Kosaka *et al*., 2010), aquatic bodies (Deka *et al*., 2013) and fodder crops (Mukherjee and Tomar, 2015), in different states of India (Munirathnam and Kumar, 2015; Duary *et al*., 2015). The data collected from different Indian agro-ecological regions over a period of 20 years revealed that most frequently encountered weed species number in Indian agriculture varied from 60 to 70 in humid, per-humid, sub-humid, coastal and island ecosystems, 30-40 in semi-arid and 15-20 in arid ecosystems (Dixit *et al*., 2008). Weeds were reported to cause yield loss of 5 per cent in commercial agriculture, 10 per cent in semi commercial agriculture, 20 per cent in subsistence agriculture (Choudhury and Singh, 2015) and 37-79 per cent in dry land agriculture (Singh *et al*., 2016). Major weed species of India in different situations are given as follows.

Crop lands

Phalaris minor (Retz.), *Echinochloa crus-galli* (L.), P. Beauv (L.), *Ageratum conyzoides* (L), *Cyperus rotundus* (L.), *Cynodon dactylon* (L.), *Parthenium hysterophorus* (L.).

Non-crop lands

P. hysterophorus (L.), *Lantana camara* (L.), *Mikania micrantha* (Kunth), *Mimosa invisa* (Martius), *Ageratum haustonianum* (Mill). *Saccharum spontaneum* (L.), *Chromolaena odorata* (L.) and *Alternanthera sessilis* (L.).

Water bodies

Major aquatic weeds of concern in India are: *Eichhornia crassipes* (Mart.) Solms, *Salvinia molesta* (Mitch), *Hydrilla verticillata* (L.f.) Royle, *Typha angustata* Bory and Chaub. and *Alternanthera philoxeroides* (Mart.) Griseb.

Parasitic weeds

In several states of India parasitic weeds are infesting crops, ornamental plants, hedges and trees and are causing economic losses. Major parasitic weeds of India include: *Orobanche cernua* (Loefl.) in tobacco, tomato, potato, *Striga asiatica* (L.) Kuntze in maize, sorghum, pearl millet), *Cuscuta reflexa* (Roxb) in niger, greengram, blackgram, berseem, lentil, linseed chickpea. *Dendrophthoe falcata* (L.f.) in neem, mango, pomegranate, sugar apple.

Obnoxious weeds

Many invasive, obnoxious and harmful weeds like *Lantana, Ageratum*; *Parthenium, Mikana, Chromolaena* and *Minosa etc*. have encroached terrestrial areas by replacing the

native flora and threatening the existence of wild animals. These weeds have invaded vast areas of forest, grassland, wastelands, orchards and plantation crops.

Deleterious impacts of weeds on blackgram

Weeds extend harmful effects slowly, steadily and inconspicuously and the effect is almost irrecoverable. Weeds may affect man's agricultural and non-agricultural activities through various ways. Some harmful effects of weeds are described below:

Reduction in land value

Weeds reduce the value of the land. Heavy infestation by perennial weeds could make the land unsuitable or less suitable for cultivation resulting in loss in its monetary value.

Limited choice of crops

Crops differ in their ability to compete with weeds. In many instances, the presence of particular weeds in fields limits the choice of crops to be grown. Very heavy weed infestations render some economically important crops, particularly pulses, jute and forage crops, unsuitable or less suitable for cultivation.

Increases cost of labourer

Presence of weeds increases the cost of agriculture and hinders the progress of work. Because of weeds more time is spent in land preparation and cultivation, cleaning, irrigation and making drainage channels, harvesting and cleaning grains.

Increases cost of disease control

Weeds harbour insects, pests, nematodes, pathogens, parasites and microorganisms. Weeds serve as hosts for insects and disease organisms, which move parasitize nearby crop and ornamental plants. Weeds like wild oats and some perennial grasses harbour pathogens of black stem rust of wheat. By harbouring these insects and pathogens, their attack on crop plant is increased. This results in increased cost of their control.

Reduction in crop yield

Weeds grow in the fields where they compete with crops for soil nutrients, water, light and space and believed to decrease crop yields. More water and nutrients are necessary to raise a ton of weeds than to raise a ton of most crops. Reduction in crop yield has a direct association with weed competition. Generally, an increase in one kilogram of weed growth corresponds to reduction in one kilogram of crop growth. Weeds remove plant nutrients more efficiently than crop plants. Competition for light and space with the concomitant reduction in photosynthesis leads to crop losses.

Loss of quality of crop produce

In crop lands and forests, weeds compete with the beneficial and desired vegetation, reducing the yield and quality of produce. The quality of leafy and other vegetable crops suffers on account of weeds. Contamination of other noxious weed seeds greatly reduces the value of crop seeds and grains and sometimes even renders them unmarketable.

Reduce human efficiency

Weeds cause health hazards to man and animals. They reduce human efficiency through physical discomfort caused by allergy and poisoning. Weeds also cause itching, hay fever and other debilitating allergies which may contribute markedly to chronic human illness and suffering. Poisoning of human beings by weeds is probably rather rare but though grazing animals often avoid poisonous plant pasture, they do not variably do so and if they are unable to discriminate against them in hay or silage, serious losses can occur.

Super-weed (herbicide-resistant): An alarming threat

Herbicide-resistant weeds are often referred to as "super-weeds". It is also known as an alarming threat. In other sense, it is nuisance plant that has developed resistance to one or more herbicides. Super-weeds are the wild plant that has been accidentally pollinated by a genetically modified (GM) plant and have abilities to resist herbicide. In other words, Super weeds are super only in their ability to resist one or more specific herbicides (Nalia *et al*., 2019). Aside from that, there is nothing that separates them from any other weed found in a farmer's field.

The advances in molecular biology and biotechnology have enabled scientists to develop crop plants which resist the application of non selective herbicides. In fact, imparting resistance to normally herbicide susceptible crops to produce herbicide-tolerant crops (HRCs) has been the most extensively exploited area of plant biotechnology. HRCs have the potential to improve the efficiency of weed management and facilitate resource conservation technologies (RCTs) adoption in India. Once the HRCs are introduced in India by private sector, integration of it with resource conservation tillage strategies will benefit the Indian farmers and will address productivity, profitability and sustainability issues in crop production. However, important risks associated with HRCs, such as the potential transfer of the gene conferring the HR trait to related wild and weedy relatives, should be examined thoroughly prior to their permission for wide spread adoption. The bio-safety concerns that are to be addressed include possible development of super weeds due to transgene movement to other varieties and wild relatives, genetic diversity erosion; ecological disturbance, adverse impact on non-target organisms, emergence of more virulent forms of weeds, pests and pathogens. It is essential to develop capacity building programs for extension workers and farmers in transgenic technology and its proper use with prudent compliance of biosafety measures.

Weed management approaches in summer sown blackgram

Weed management is the combination of the techniques of prevention, eradication and control to handle weeds in a crop, cropping system, or environment. Weed prevention, eradication, control and management are separate terms and each utilizes and combines various technologies. The first basic step in such technology is to prevent the weed infestation in a locality in order to avoid future problems. If one fails prevent weeds, a step must be taken towards eradication. Eradication is restricted to very small scales and only if suitable methods of complete weed removal are available as eradication is cent per cent control of weeds along with its root system and other propagation components. In case, we fail in prevention and eradication techniques then weed control method must be strictly followed in which the objective is to bring down the weed population (with any method) to a level that economical crop yield is possible. In comparison, weed management is a system approach that manages whole land usage in advance to minimize the invasion of weeds in aggressive ways. In this context, different weed control methods like cultural, physical/mechanical, biological, chemical and integrated weed management practices are used to control weeds.

Cultural weed management

Globally, cultural control approach is one of the most widely approach in blackgram. It provides competitive advantage to crop against weeds by reducing weed establishment (Singh, 2014) and through selective stimulation, facilitating faster crop growth to smother weeds (Das *et al*., 2012). Several cultural practices like field preparation, summer tillage, maintenance of optimum plant population, crop rotation, cover crops, fertiliser application, irrigation and drainage, growing of intercrops, mulching and soil solarisation *etc*., are deployed for creating favourable condition for the crop. These practices if used properly help in controlling weeds. Soil solarisation is a novel technique of controlling soil born weeds including pests in blackgram. It involves covering the wet soil with thin transparent polythene films in the summer months. The process would raise the surface soil temperature by 8-12°C as compared to non-solarised soils. Duration of 4 to 6 weeks is sufficient to give satisfactory control of weeds. Many annuals, some perennials and parasites weeds are sensitive to this treatment. Besides, controlling the weeds, soil solarisation is reported for improvingthe availability of nutrients in soil that further benefits the microflora, ultimately resulting in an increased response to plant growth in several crops including blackgram.

Mechanical/physical weed management

This process of weed control came into practice from the time crops were cultivated. The mechanical methods include tillage, hoeing, hand weeding, digging cheeling, sickling, mowing, flooding and flaming and steaming *etc*. Manual weeding is laborious, time consuming and back breaking and thus effective mechanical weeders are being developed for weeding operation and help toachieve expected farm yield. Although, it has undergone a spectacular advancement, it is easily operating with basic weeders, economically more effective to monitor weed flora and to improve crop productivity. While the weeds in intra-row spaces or near the crop could not be controlled, the rotary weeders were efficient for controlling weeds.

Biological weed management

In general, weeds are managed either manually or by using herbicides, but theformer it relatively expensive, time consuming whereas the later cause soil/ water pollution, severe financial burdens and require technical knowledge to be used. To solve these problems, biological control came up as a best option for weeds control in blackgram. Biological suppression is an effective, environmentally safe, pollution free, economically viable, technically appropriate and socially method of weed management in blackgram. Insects, mites, nematodes, plant pathogens, animals, fish, birds and their toxic products are major weed controlling biotic agents and among these insects are one of the important groups (Tiwari *et al*., 2013; Kumar, 2014; Verma *et al*., 2015).

Chemical weed management

Due to unavailability of labour on time, labour being expensive, onset of monsoon and rains , hand weeding is difficult, so, the option to control weeds come applying chemical management in place as late weeding or no weeding can lead to severe yield loss. Chemical weed control by pre-sowing, pre-emergence and post-emergence use of herbicides and combinations of them are successful ways to control weeds in the first few weeks after crop sowing. The use of herbicides has been stimulated by a widespread increase in farm wages for consistently increase the economic levels of farms as well as provide the non-farm employment opportunities and drastically use of herbicide as a result of rising opportunity costs of labour across the developing world. Based on income and labour use per hectare, herbicide technology has been shown to be superior to different weed management methods in blackgram. In order to create an awareness or knowledge to farmers about the proper use of pre- and post-emergence herbicide techniques to monitor weed flora in blackgram.

Pre- and post-emergence herbicides and its effect on weeds

Pre-emergence herbicides are used one or two days after sowing of a crop but before the emergence of crop. Although, the emergence of crop is considered, the emergence of weeds is equally important for designating many herbicides pre-emergent. A variety of pre-emergence herbicides such as pendimethalin, oxyfluorfen, nitrofen,

alachlor, clethodium, terbutryn, fluchloralin, etc. are used to control the germination of weeds in blackgram at early stages. Pre-emergence herbicide is preferred because of its better efficiency along with time involvement. Furthermore, it causes no mechanical damage to the crop that happens during manual weeding (Murti *et al*., 2004).

Effective weed control depends on the proper selection of herbicides, type of weed flora infesting the crop, time of application and further use of optimum dose of herbicide (Chum *et al*., 2010). Singh *et al*. (1982) reported that pre-emergence application of pendimethalin (2 Kg/ha) in blackgram caused significant decrease in number and dry weight of weeds and gave significantly higher yield than weedy check at Pantnagar and Jain *et al*. (1988) reported that pre-emergence application of pendimethalin (2 Kg/ha) revealed eight fold decrease in weed population and two fold increase in seed yield of blackgram. Application of pendimethalin as pre-emergence @1.5 kg/ha along with hand weeding at 30 DAS observed maximum weed control efficiency, it lead to increase the productivity of blackgram (Ramanathan and Chandrashekharan, 1998). Kumar and Tewari (2004) demonstrated cent per cent mortality of *Trianthema monogyna*, a major dominating broad-leaved weed using herbicides *viz*., pendimethalin (1.00 kg ha^{-1}) as pre-emergence. In the same way, pre-emergence application of pendimethalin at 1.50 kg/ha in combination with raised seed bed and ridge planting was effective to control *Polygonuma latu* and *Ageratum conyzoides* (Kumar and Angiras, 2005) and improving the physiological parameters (dry matter production, leaf area index and chlorophyll content) and further develop the nodules in urdnean were significantly influenced by fluchloralin @ 1.0 kg/ha followed by pendimethalin @ 0.75 kg/ha (Murti *et al*., 2004). Almost certainly, application of pendimethalin (0.75 kg/ha) plus hand weeding at 30 DAS drastically reduced density and dry weight of *Trianthema monogyna* (Sharma and Yadav, 2006). Consequently, pendimethalin @ 0.75 kg/ha in integration with one hand weeding at 45 DAS resulted in highest seed yield of blackgram and minimum weed number and dry matter accumulation as observed by (Kumar and Angiras, 2005). However, the highest seed and haulm yield as influenced by pendimethalin at 0.75 kg/ha as pre-emergence along with one hand weeding at 40 DAS in summer blackgram (Patel *et al*., 2011).

The use of post-emergence herbicides alone or in combination may broaden the window of weed management by broad-spectrum weed control (Hemlata *et al*., 2016). Recently, some new post-emergence herbicides *viz.* fluazifop-p-butyl, imazethapyr, acifluorfen sodium and clodinafoppropargyl, quizalofop ethyl, fenoxaprop-p-ethyl, cyhalofop-butyl *etc*. are being marketed with the assurance of selective control of weeds in blackgram. Imazethapyr may be applied as pre-plant initiation, pre-emergence or as post-emergences (York *et al*., 1995). Kumar and Tewari (2004) demonstrated cent per cent mortality of *Sorghum halepense,* a perennial grass using fluazifop-p-butyl (0.375 kg ha^{-1}) as post-emergence in blackgram. Although, application of fenoxaprop-p-ethyl @ 60 g/ha effectively controlled the predominant weeds like *Echinocloacolonum* and *Paspalum distichum* and recorded significantly lower weed dry matter and higher grain yield (Reddy *et al*., 2000). Similarly, post emergence application of tralkoxydin @ 0.4 kg/ha and fenoxaprop-p-ethyl @ 80 g/ha at 30 DAS recorded significantly lower weed dry weight, weed density and recorded higher weed control efficiency and grain yield of blackgram on clay loam soil (Chopra, 2001).

Rao and Ramana (1997) observed that pre-emergence application of pendimethalin 1.0 kg/ha followed by post-emergence application of fluzifop-p-bytyl or sethoxydim 0.25 Kg/ha, 20 days after sowing, was more effective in reducing weed growth and increasing seed yield of blackgram and was comparable to hand weeding twice at 20 and 40 days after sowing, which recorded the highest seed yield. Gupta *et al*. (2017) conducted an experiment to study the effect of pre and post-emergence herbicides in blackgram. The experiment was laid out with 12 treatments, *viz*. imazethapyr with four application rates 70 and 80 g/ha as pre-emergence (PE) and 70 and 80 g/ha as post-emergence (PoE); imazethapyr+imazamox (RM) 70 and 80 g/ha as PE and 70 and 80 g/ha as PoE, pendimethalin 1000 g/ha as PE, pendimethalin + imazethapyr (RM) 1000 g/ha PE, two hand weedings at 20 and 40 DAS (weed free) and weedy check in a randomized block design. Two hand weeding at 20 and 40 DAS were found to be very efficient in controlling the dominant grassy weeds and gave maximum seed yield (924 kg/ha) *fb*ready mix herbicides *i.e*. imazethapyr + imazamox 80 g/ha as PoE (905 kg/ha) and pendimethalin + imazethapyr 1000 g/ha as PE (879 kg/ha). Similarly, Sakthi and Velayutham (2018) conducted an experiment to evaluate the effect of pre- and post-emergence herbicides on weeds and productivity of blackgram. In this experiment, they concluded that PE application of oxyfluorfen @ 0.18 kg ha^{-1} + EPOE Imazethapyr @ 0.05 kg ha^{-1} on 20 DAS (T9) or PE application of pendimethalin @ 1.0 kg ha^{-1} + EPOE imazethapyr @ 0.05 kg ha^{-1} on 20 DAS (T7) was found to be the viable weed management practice for achieving higher productivity of blackgram. While Prajapati *et al*. (2018) recorded significantly higher seed yield in blackgram using the post-emergence application of imazethapyr at 60, 75, 100 and 150 g/ha than pre emergence application of pendimethalin and alachlor. Recently, some new post emergence herbicides, namely, imazethapyr, fenoxaprop-p-ethyl, cyhalofop butyl, clodinafoppropargyl, quizalofop ethyl and aciflourfen sodium *etc*. are found to be effective in selective control of weeds in blackgram. Application of fenoxaprop-p-ethyl @ 75 g ha^{-1} or cyhalofop butyl @ 100 g ha^{-1} drastically reduced the density of grassy weeds (Sasikala *et al*., 2019). Moreover, according to Singh *et al*. (2016), pre-mix combination of imazethapyr + pendimethalin at 1000 g/ha had maximum efficiency to knock down weeds in comparison to application of herbicides applied as pre or

post-emergence in isolation. Pre-mix combination of imazethapyr + pendimethalin also proved to be effective in improving other parameters like plants/m^2, pods/plant, seed/pod and 100 seed weight (Mansoori *et al*., 2015).

Allelopathy: A tool for sustainable weed management

Allelopathy is a natural ecological phenomenon by which one organism produces biochemicals that influence the growth, survival, development and reproduction of other organisms. These biochemicalsare known as allelochemicals and enter the environment through plant degradation, volatilization, leachimg from plant leaves and root exudation (Farooq *et al*., 2011; Farooq *et al*., 2013; Dahiya *et al*., 2017; Cotruþ *et al*., 2018). Plant allelopathy is one of the modes of interaction between receptor and donor plants and may exert either positive effects (*e.g*., for agricultural management, such as weed control, crop protection, or crop re-establishment) or negative effects (*e.g*., autotoxicity, soil sickness, or biological invasion). These interactions play a significant role in plant-plant and plant-microbial interactions. Various allelopathic interactions including weed-weed, weed-crop and crop-crop also have been observed. Allelopathy is being recognised as tool of weed management in blackgram by weed scientists in the present day scenario. Saranya *et al*. (2019) conducted an experiment to assess the allelopathic effect of *Parthenium hysterophorus* and *Tridax procumbens* aqueous leaf extracts on weed control and growth of blackgram. The role of allelopathy in weed management has been discussed in detail by Dahiya *et al*. (2017). He suggested that allelopathy can be used to control and may offer substitute for chemical control or reduce the dose of herbicides. The growing demand for sustainable agricultural systems requires that researchers re-evaluate current production methods and inputs. To ensure continued productivity and potentially reduce synthetic herbicide requirements, allelopathy has become a focal point for research in the agricultural community. Although, scientists are sceptical about the utilization of allele-chemicals for weed suppression but it remains a promising avenue for reducing herbicide usage. Whether through the development of natural herbicides from isolated allele-chemicals or through the application of cover crops with allelopathic properties, allelopathy will most likely be a factor in providing sustainable systems in the future (Dahiya *et al*., 2017).

Integrated weed management

Continuous use of herbicides may cause environmental pollution and may lead to development of resistance in plants against these chemicals (Shweta *et al*., 2017). Therefore, it is necessary to utilize more than one method of weed control for sustaining the productivity and profitability of crops and cropping system. From various experiment conducted across the country, it can be interpreted that a combination of chemical molecule and one manual weeding led to better yield in comparison to either used in isolation. Malik *et al*. (2000) at Hisar indicated the performance of trifluralin 0.75 kg/ha, linuron 0.75 kg/ha and acetachlor 1.0 kg/ha (all as pre-emergence) each integrated with a single weeding at 30 DAS was superior and produced high yields in comparison to then when applied alone in urdbean. Similarly, combined results in cultural (seed rate), mechanical (hand weeding at 40 DAS) and chemical methods (pendimethalin @ 0.75 kg/ha) greatly reduces blackgram's weed density and dry weight, resulting in higher production and cost-effectiveness (Velayudham, 2007). The usage of pendimethalin (1.00 kg/ha) or oxyfluorfen (0.18 kg/ha) as pre-emergence herbicides accompanied by mechanical weeding (hand weed + inter cultivation or two hand weeding at 20 and 40 DAS respectively) produces a stronger control over weeds and also provides farmers with an economically healthy climate (Balyan *et al*., 2016). The weed density was substantially decreased by the post-emergence herbicide as quizalofop-ethyl 50 g/ha in 30 DAS and was significantly higher with the care of inter-culture 15 DAS fb imazethapyr 100 g/ha 30 DAS, inter-culture 15 DAS fb Quizalofop-ethyl 50 g/ha in 30 DAS and imazethapyr 100 g/ha in 20 DAs (Singh *et al*., 2016). Crop cultivated under line sowing with the use of quizalofop ethyl @ 50 g/ha reported the lowest dry weed weight with large bed system and on ridge (Darvin *et al*., 2015). In addition to a decrease of 63.2 and 62.3% in the pre-mix application of imezathapyr + pendimethalin (1000 g/ha), or imazethapyr + imazamox (pre-mix) of 70 g/ha, both in terms of improved herbicide combination efficiency may benefit from the synergistic impact between the two herbicides which decrease the weed population and the accumulation of dry materials of different weed species (Rao *et al*., 2010).

Regulation of various methods of weed control would provide the competitive advantage to crop over weeds. The integration of these methods with chemical measurements is recommended to prevent the harmful effects of herbicidal reliance alone. Some of the negative effects of sole dependence on herbicides are evolution of shift in herbicide resistance weed flora and soil and environmental pollution (Sanbagavalli *et al*., 2016). In addition, continual reliance on the single weed control system contributes to plant flora towards developing resistance towards herbicides thus, making it all the more difficult to control weed species. Thus, a combination of various weed control management practices need to be placed together *i.e*. the integrated weed management techniques in order to cope up with this issue. The rising cost of labour and input would reduce farmers' incomes unless an integrated approach is implemented, based on ecology and herbicides.

CONCLUSION

The above stated review indicates that, weeds must be managed for successful crop production by attaining high yields. In a world, where approximately two billion people

have to be fed over the next 50 years, significant crop losses owing to weeds are quite alarming. Based on the resources available we need to prioritise and adopt the best suitable weed control strategies like cultural, physical/mechanical, biological and chemical management method by pre-emergence and post-emergence application of herbicide and combinations of them which will significantly lead to decrease in the weed population, that will ultimately help in attaining higher yields. Several weed scientists have recently suggested that allelopathy could be used to control and may offer substitute for chemical control or reduce herbicide dose. To sum up, integrated weed management method is the essential to sustainable crop cultivation worldwide and will be the key to weed management in the foreseeable future.

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Conflict of interest

Authors have no conflict of interests.

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