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A review on weed management techniques in greengram

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Abstract
Greengram is the third important pulse crop of India. Among the various factors responsible for poor yield in greengram is an inadequate weed control measure. Weed infestation is one of the major constraints in greengram cultivation and causes 50 to 90% yield loss. Weeds have to be controlled for successful crop production. Significant crop losses due to weeds are simply not acceptable in a world where two billions more people will have to be fed in the next 40 years. Traditional practice of hand weeding requires dependence on increased number of labour during peak period of sowing and harvesting and becoming expensive However weeding through implements *i.e.*, mechanical way is economical and time saving; it is not satisfactory in a broadcast or mixed cropped area. For effective and timely weed control in crop plants use of herbicides with proper liable techniques has become a common practice Based on the resource available to have adopting the best suitable weed control strategies like cultural control, mechanical methods, Herbicide adoption and integrated approaches will significantly decrease the weeds, which will lead to even greater yields. Finally, integrated weed management is the key to sustainable crop production throughout the world and will remain the mainstay for weed control for the foreseeable future.

Keywords: Green gram, yield loss, weed control, cultural control, mechanical methods, herbicide, IWM

Introduction
Greengram is the third important pulse crop of India. It is the cheapest source of dietary protein. It is consumed in various forms as whole or split, husked and unhusked. It is rich in protein, carbohydrate, fat, amino acids, vitamins, and also provides large quantity of green fodder which serves as the nutrition food for the livestock. It can be grown in all the seasons of the year. Green gram improves the soil health and maintains its environment. Hence it can be grown as sole crop, intercrop, mixed crop and in sequential cropping systems.

Among the various factors responsible for poor yield in greengram is an inadequate weed control measure. Weed infestation is one of the major constraints in greengram cultivation and causes 50 to 90% yield loss (Kumar *et al.,* 2006) [24]. Competition with the weeds leads to 30 to 80% reduction in grain yield of greengram during summer and *kharif* seasons while 70-80% during *Rabi* season respectively. (Algotar *et al.,* 2015) [3]. Weed control is one of the essential agronomic measures to exploit the maximum yield potential of the newly developed high yielding varieties. (Singh and Sheoran, 2008) [44] reported that the weed infestation if not checked within 20 DAS there would be a severe yield reduction to an extent of 38 per cent in contrast to 20 per cent yield reduction with unchecked weed infestation till 20 DAS in greengram. Traditional practice of hand weeding requires dependence on increased number of labour during peak period of sowing and harvesting and becoming expensive (Vivek *et al*., 2008) [57]. However weeding through implements *i.e.*, mechanical way is economical and time saving; it is not satisfactory in a broadcast or mixed cropped area.

For effective and timely weed control in crop plants use of herbicides with proper liable techniques has become a common practice. Higher rate of herbicides may leave residue (Fand *et al*., 2013) [14] to succeeding crops. Use of herbicides in conjunction with cultural practices or other practices would make complete control of weeds and will be acceptable by the poor farmer (Ayansina *et al*., 2003) [5]. Hence, development of an integrated weed management is economically viable as well as ecologically safe for effective weed control and enhances the productivity of greengram.

Common weed spectrum in greengram field

Weed flora in greengram crop differ from region to region with soil conditions. Generally, weeds are found in larger numbers with more aggressive nature, because of their wider adaptability even under extremities of climate, edaphic and biotic stresses. High persistence nature of weeds is attributed to their ability of high seed production and seed viability. One should have good knowledge about the persisting weed flora for better management to gain more yield. The information on the weed spectrum of greengram fields is essential for the formulation of effective weed control strategies. The major weed flora found in greengram under sandy loam soil of Rajendranagar, Andhra Pradesh were *Cynodon dactylon, Dactyloctenium aegyptium, Celotia argentia, sedges viz. Cyperus rotundus and* broad-leaved weeds *viz. Digeraarvensis, Trianthema portulacastrum, Commelina bengalensis, Parthenium hysterphorus, Euphorbia hirta, Hemidismus indica* (Nagender *et al.,* 2016) [34]. Similarly in sandy loam soil of Naida (West Bengal), the experimental field was dominated with following weed flora such as Ageratum *conyzoids, Boreria hispida, Commelina banghalensis, Echinochloa colona, Cynodon dactylon, Paspalum scrobiculatum, Digiteria sanguinalis*and *Cyperus rotundus* (Tamang *et al.,* 2015) [53].

In deep black soils of Navsari Agricultural University, Navsari (Gujarat) the weed flora consisted of *Cyperus rotundus, Echinochloa crusgalli, Digitaria sanguinalist, Sorghum halepense, Cynodon dactylon, Amaranthus viridis, Alternanthera sessillis, Digera arvensiss* and *Convolvulvulus arvensis* (Chaudhary *et al.,* 2016).

In medium black soil of Junagarh, Gujurat *Panicum colonum* L., *Cynodon dactylon* L., *Cyperus rotundus* L., *Digera arvensis* Forsk, *Euphorbia hirta* L., *Leucas aspera* Spreng., *Phyllanthus niruri* L., *Portulacaoleracea*L., *Indigoflora glandulosa* L., *Phyllanthus niruri* L. were found (Chhodavadia *et al.,* 2013) [8].

Under clay loam soil of Dharwad, Karnataka; broad leaved weeds (BLW) like *Digera arvensis* Forsk, *Amaranthusviridis* L., *Commelina benghalensis* L., *Cyanotis cucullata* L., *Phyllanthus niruri* L. and *Argemone mexicana*; grasses like *Brachiariae ruciformis* L., *Cynodon dactylon* L., *Digitaria sanguinalis* L. and *Dinebra retroflexa* L., and sedge *Cyperus rotundus* L. are dominant (Shruthi and Salakinkop, 2015) [46].

Amaranthus spinosus, Digera arvensis, Trianthema portulacastrum, Gisekia poredious, Euphorbia hirta, Aristida depressa, Portulaca oleracea, Cenchrus biflorus, Cleome viscosa, Tribulus terrestris, Corchorus tridense, Cyperus rotundus, Eleusine verticillata, and *Aervato mentosa*were the dominant species under loamy sandy soil of Bikaner, Rajasthan (Komal *et al.,* 2015) [22].

In sandy loam soils of Ludhiana, Punjab *Cyperus rotundus and Trianthema portulacastrum* was the major weed flora found in summer greengram (Kaur *et al.,* 2009) [18]

Crop weed competition

Life cycle of most of the weeds coincide with that of crop they invade, thus ensuring mixing of their seed with those of the crops (Mahroof *et al.,* 2009) [29]. Due to diversity, weeds are major threat to agriculture and they out-compete crops for natural resources utilization (Chhodavadia *et al.,* 2013) [8]. Crop weed competition has been established as a major limiting factor for its low productivity causing yield reductions to the extent of 40 to 80 per cent depending upon type and density of weed species present in the field.

Weeds, being naturally hardy and emerge faster, cause severe competition at an early stage of crop in respect of light, nutrients, water and space reflecting in considerable reduction in crop yield. Thus, it becomes essential to study crop-weed competition scientifically and how it can be reduced to maximum (Phajage *et al.,* 2014) [38]. Crop need a weed free period of first 30 days, as the crop is short statured which suffers badly if weeds are not controlled at early stage (Mirjha *et al.,* 2013) [31]. Weed competition with mungbean persisting for 20-30 days after emergence was very critical and prolonged competition resulted in substantial yield reduction (Naeem *et al.,* 1990) [33].

Weed competition is very severe during rainy period, particularly at early stages (30 to 45 days after sowing) of the legume crops and hence early weed control is essential (Aktar *et al.,* 2015) [2].

Initial 45 days period is considered to be critical period with respect to crop weed competition in green gram (Singh *et al.,* 1996) [49]. In general, competition between crops and weeds was more severe when the competing plants have similar vegetative habits and demands upon resources.

Effect of weed management on

Grain yield

Weeds compete with the crop plants for all the resources required for growth like space, water, sunlight and air and cause reduction in crop yield. Depending on weed type and crop weed competition it reduces crop yield up to 96.5% (Verma *et al.,* 2015) [55], whereas the loss of mung bean yield due to weeds ranges from 65.4 to 79.0% (Dungarwal *et al.,* 2003) [13]. Weed competition reduces the grain yield of summer greengram by 34.9% during initial first 30days after sowing, there after it increases to 49.15% (Singh *et al*., 1996) [49]. The Competition with the weeds throughout the crop season reduced the seed yield of mungbean by 83.3% (Mishra *et al*., 2000) [30]. The weeds infestation if not checked after 20 DAS, severe yield reduction (Parvender *et al*., 2008) to the extent of 38 per cent was recorded in contrast to 20 per cent yield reduction with unchecked weed infestation till 20 DAS.

Nutrients

Nitrogen (N), phosphorus (P) and potassium (K) are the primary plant nutrients required for plant growth. When the crop growth is interfered by weed growth, it reduced the nutrient utilization of crop plant. In general, weeds have a larger nutrient requirement and will absorb as much or more than the crop. In the same way, adoption of weed management practices significantly enhanced NPK uptake by greengram and reduced removal of nutrients by weeds as compared to that of unweeded check (Chhodavadia *et al.,* 2013) [8]. Weeds removed 61.9, 12.1 and 51.3 kg/ha of N, P2O5 and K2O kg/ha respectively in weedy plots (Komal *et al.,* 2015) [22]. Stoimenova (1995) [51] reported that decreased nutrients uptake by the crop was noticed with increase in severity and duration of weed infestation.

Quality of grain

A heavy infestation of weeds hampers not only the growth and yield as well as infest the quality of pod or seed. Protein content of greengram significantly influenced by weed management practices. Unweeded check reduced the protein content to 18.26 in greengram (Chhodavadia *et al*., 2013) [8] compared to adoption of two hand weeding and two interculturing at 20 DAS & 40 DAS (22.15%) and oxyfluorfen @ 0.180 kg/ha+ 1 hand weeding at 30 DAS

(21.87%). The experiment laid out on summer mungbean at Pantnagar (Uttaranchal) and noted that protein content was significantly higher in weed free plots and the lowest in weedy check plot. Harmoniously, the weed species are affecting the quality of pod size and seed due to long time presence of weed growth and also reducing the market value of produces (Devi, 2004) [12]. Thus weed flora as well as weed population in unweeded control plot affected quality adversely.

Weed management strategies in greengram

Weed free crop situation has creating stable place to crop for getting effective growth environmental circumstance. Besides causing crop losses, weeds are also responsible for reducing crop quality, nutrient status of soil etc. The weeds can be checked by adopting various methods like eco-physical, biological, chemical and recently through combining direct and indirect approach i.e. integrated weed management. Wherever, select the weed control techniques based on the economic threshold levels of weed growth for providing weed free competition and also reduce the environmental biodiversity (Adpawar *et al*., 2011) [1].

Manual Methods

In India, weeds are controlled mostly either manually or mechanically in greengram. Manual weed control techniques manage weed populations through physical methods that remove, injure, kill, or make the growing conditions unfavorable. Hand weeding at 20-25 DAS and followed by another weeding at 12-15 DAS interval up to 50-55 days of the crop. One of the important method of hand weeding by hoe is effectively controlling the weed species especially *Cyperus rotundus* in the inter row spaces of a line sown crop. This method might be provides good physical and environmental condition to the crop growth by way of soil aeration through stirring of the soil. Still now, this method could be effective for eliminating weeds particularly annual and biennial weeds in cropped and non-cropped situations. Hand weeding at 20, 30 and 40 DAS reduced weed infestation most efficiently throughout the growing period of the crop and as a consequence it produced the highest seed yield of summer green gram (Chhodavadia *et al.,* 2014) [9].

Hand weeding at 20 and 30 DAS and hand hoeing at 20 and 30 DAS was enhanced the yield of greengram by 3.4%, 3.6% over weedy check (Chaudhari *et al.,* 2016) [7]. Patil *et al.,* (2014) [37] reported that at Akola, Maharashtra, hand weeding + 1 hoeing increased the grain yield by 68.9% over control. Removal of weeds by means of interculturing and hand weeding at 20 and 40 DAS reduced the weed population, dry weight of weeds and improved the weed control efficiency, yield attributes, yield and protein content in greengram (Gelot *et al*., 2017). For all that, lower weed biomass, lesser weed density, weed index and weed control efficiency were observed with hand weeding followed by mechanical weeding in both greengram and blackgram (Veeraputhiran, 2009) [54].

Mechanical Methods

In the recent past, weed control is affected more by chemical means supplemented by mechanical weeding. Increasing demand for labour and escalating cost of agro-chemicals together with phytotoxicity effects pose the farming community to think of mechanical measures, which will help the crop production to free itself from the scourge of weed menace with limited labour (Kathiresan, 2002) [17]. Mechanical weeding can be done by unskilled labour and is generally economical, non-polluting without residual problems and is relatively safe to the operator.

In the past, there were no mechanical weeders to fight this enemy and farmer had to use his hands to pull them out. Manual weeding is laborious, back breaking and time consuming and hence efficient mechanical weeders are being developed for weeding operation and help to obtain expected yields from the farm. Although it has undergone a spectacular advancement, to use of simple weeders with hand weeding and it would be easily operating, economically more effective in controlling the weed flora and led to increase the productivity of crops (Sumachandrika *et al*., 2002). Rotary weeder was effective in controlling weeds present in inter-row space, but failed to control the weeds in intra-row space or those in vicinity of the crop (Choubey *et al*., 1998) [10]. Similarly (Lidhoo, 2004) [28], use of improved weeders increased yield from 169.5 per cent to 329.6 per cent over control.

Mechanical control of weed controls because physical changes in the immediate environment that may cause positive or negative effects. The suppression of the targeted weeds will open niches in the environment and may also stimulate the growth of other weeds by decreasing their competition and making their environment more favorable. If a desirable plant does not fill the niches, they will eventually be taken over by another weed.

Cultural Methods

Weed control is one of the most important objectives of cultural operations. Following proper cultural operations is more than half the weed control envisaged on a farm. While directly it includes a healthy growth of crops, indirectly it maintains a crop environment that is detrimental to weeds. Among the crop management practices, method of planting plays a major role in controlling weeds. The reduction of *E. Colona* in bed planting of greengram may be due to more foliage growth of bed planted green gram which caused hindrance in germination of weeds and deeper burial of weed seeds during formation of raised beds (Rekha Yadav *et al*., 2019).

Muching can suppress weeds, due to delayed emergence and smothering effect on weeds especially on broad leaves as compared to grassy weeds (Radwan and Hussian, 2001) [40]. In greengram, dust mulching significantly reduced the weed dry weight and density which resulted in more uptake of nutrients by the crop and finally increased the yield (Verma *et al*., 2008) [56]. Besides various methods of weed control. A good crop cover by adopting right inter-row and intra-row spacing will smother the growth of the weeds.

Chemical Methods

Hand and mechanical control methods are used on a large scale but, cost is very high, unfavorable weather and soil condition and also the labours are not available at proper time. The chemical control of weeds is found to be effective and economical in initial stages of growth. The use of herbicides has gained impetus from the general rise 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 (Hossain, 2015) [2]. 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) [11].

Pre-emergence herbicide

Pre emergence herbicide is preferred because of its better efficiency along with time involvement. Also, it causes no mechanical damage to the crop that happens during manual weeding (Ram Murti, Khan *et al*., 2004) [32]. Pre-emergence herbicides are applied one or two days after sowing of a crop but before the emergence of crop. Major pre-emergence herbicides *viz.,* Pendimethalin, Oxyfluorfen, Fluchloralin, Clethodium, Terbutryn, etc are used to control the germination of weeds in greengram at early stages.

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 greengram (Chaudhari *et al*., 2016) [7]. 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 *Polygonumalatu*and *Ageratum conyzoides* (Kumar and Angiras, 2005) [23]. Pre emergence application of pendimethalin @ 1.00 kg/ha or imazethapyr 100 g/ha in greengram reduced weed density and dry weight (Leva *et al*., 2018) [27]. The pendimethalin was ineffective against sedges and lost its efficacy after 20 days of application against grasses and broadleaves. Application of pendimethalin + imazethapyr provided effective control of all the grass weeds and created weed free conditions till first 40 days of sowing (Kaur *et al*., 2016) [19]. Glyphosate spraying on zero tillage condition at 7 days before sowing plus one hand weeding at 25 days after emergence would be economic for mungbean production, besides reducing the density of *Echinochloa crusgalli, Digitaria sangunalis* and *Cyperus rotundus* (Khan *et al*., 2014) [21].

Post emergence herbicides

The use of post-emergence herbicides alone or in combination may broaden the window of weed management by broad-spectrum weed control (Nirala *et al*., 2016) [35]. Recently, some new post emergence herbicides *viz*. Imazethapyr, Acifluorfen sodium and Clodinafop propargyl, Quizalofop ethyl, Fenoxaprop-p-ethyl, Cyhalofop-butyl *etc*. are being marketed with the assurance of selective control of weeds in greengram.

The imazethapyr allows much flexibility in timing of the applications. Imazethapyr may be applied as pre-plant initiation, pre-emergence or as post-emergences (York *et al*., 1995) [59]. Although, (Reddy *et al*., 2000) [43] application of fenoxaprop-p-ethyl @ 60 g/ha effectively controlled the predominant weeds like *Echinocloa colonum* and *Paspalum distichum* and recorded significantly lower weed dry matter and higher grain yield.

Application of quizalofop-ethyl @ 0.040 kg/ha (WCE 36.70 percent) was most effective in controlling weeds followed by fenoxaprop-p-ethyl @ 0.075 kg/ha (WCE 36.70 percent) (Chhodavadia *et al.,* 2013) [8]. Similarly, application of Quizalofop-p-ethyl @ 50 g a.i. ha-1 at 21 DAE + hand weeding at 28 DAE recorded lower dry weight of grasses and sedges (Kundu *et al*., 2009) [25]. The combinations of Haloxyfop-p-methyl at 135 g/ha + Imazethapyr at g/ha, and Quizalofop ethyl at 50 g/ha + Imazethapyr at 75 g/ha applied at 12-15 days after sowing of green gram as an early post-emergence can be recommended for weed control in greengram (Poornima *et al.,* 2017) [39]. The maximum weed control efficiency was recorded under Imazethapyr 200 g/ha (89.26 per cent) and Imazethapyr 100 g/ha (83.65 per cent) and higher weed smothering and higher yield of green gram (Om Prakash Shivran *et al*., 2017) [45]. Pendimethalin 0.75 kg/ha as pre emergence + imazethapyr + imazamox 40 g/ha at 30 DAS as post-emergence application in summer greengram reduced weed density and weed dry weight (Komal *et al*., 2015) [22]. The post emergence application of imazethapyr at 0.075 kg/ ha applied 20-25 days after sowing was the most remunerative and effective herbicide for controlling the complex weed flora in mungbean (Khairnar *et al*., 2014) [20]. Similarly, post emergence application of Imazethapyr @ 100 g ha-1 with raised panting of greengram recorded maximum weed control efficiency (Yadav *et al*., 2019) [58]. Under constraints of labour availability, maximum yield, net profit and effective weed control in green gram crop can be achieved with application of Imazethapyr or Quizalofop-p-ethyl 100 g/ha 15-20 days after sowing was reported by Ali *et al.,* (2011) [4]. However, (Kushwah and Vyas, 2005) [26] reported that imazethapyr at 75 g/ha was effective against both monocot and dicot weeds and was at par with one hand weeding at 20 DAS, however it was more effective against grassy weeds. If enhanced the grain yield by 45.3 per cent over weedy check.

Integrated weed management strategies

Now days, a various weed control methods were found to be effective in controlling weeds in greengram and also its each other methods have their own merits and demerits based on resource available or environmental condition. However, efficient and cost-effective weed control can be achieved by using either combination of herbicides or combining herbicide alone or any one of the weed control method may not control the weeds effectively. In such condition, an integrated weed management (IWM) practice involving both chemical and other agronomic manipulation may be an efficient tool, as increasing crop density seems to be an alternative to shift crop weed competition in favour of crop.

An integrated weed management practice involving both chemical and other agronomic manipulation may be an efficient tool, as increasing crop density seems to be an alternative to shift crop weed competition in favour of crop (Shweta and Singh, 2005) [47].

In general, sequence application of weed control methods like pre emergence herbicide prevent or kill the germinated weed seeds and further vigour weed growth was controlled by hand weeding for superior methods than individual application of other control methods of weeds (Rao, 2010) [42]. Initial pre emergence application of pendimethalin 1kg a.i./ha and followed by one manual weeding minimizes total weed density throughout the crop growth period and produces maximum yield (Singh *et al.,* 2015) [55]. In the same way, application of quizalofop-p-ethyl @ 50 g a.i. ha-1 at 21 DAE and followed by one hand weeding at 28 DAE produced the highest yield attributes, seed yield and benefit: cost ratio in mungbean cultivation compared with application of herbicide alone (Kundu *et al*., 2009) [25]. Application of oxyfluorfen 0.180 kg/ha followed by one hand weeding at 30 DAS significantly superior in reducing the density of monocot and dicot weeds (Chhodavadia *et al*., 2013) [8]. Application of pre emergence herbicides as pendimethalin (1.00 kg/ha) or oxyfluorfen (0.18 kg/ha) followed by mechanical weeding (hand weed + intercultivation or two hand weeding at 20 and 40 DAS respectively) creating a better weed free situation and also provides economically safe to farmers (Balyan *et al*., 2016) [6]. Crop grown under line sowing with the application of quizalofop ethyl @ 50 g/ha recorded lowest weed dry weight followed by broad bed method and ridge method (Darvin *et al*., 2015). However, pre-mix application of

imezathapyr + pendimethalin (1000 g/ha) or imazethapyr + imazamox (pre-mix) 70 g/ha reduced total weed population by 63.2 and 62.3 per cent, respectively so given as better performance of combination of herbicides might be due to synergistic effect between the two herbicides reducing the population as well as dry matter accumulation of different weed species (Rao *et al*., 2010) [42].

Regulation of various weed control methods should be such that they give the competitive edge to crop over weeds. The continuous dependence on single method of weed control leads to shift of weed flora in favour of more tolerant and difficult to control species and to tackle this problem, there is need to adopt integrated weed management practices. The rising cost of labour and input will wipe out the profits of farmers unless an integrated approach with focused attention of ecology and herbicides is adopted.

Conclusion

The above stated review results reveals that, weeds have to be controlled for successful crop production. Significant crop losses due to weeds are simply not acceptable in a world where two billions more people will have to be fed in the next 40 years. Based on the resource available to have adopting the best suitable weed control strategies like cultural control, mechanical methods, Herbicide adoption and integrated approaches or indivual will significantly decrease the weeds, which will lead to even greater yields. Finally, integrated weed management is the key to sustainable crop production throughout the world and will remain the mainstay for weed control for the foreseeable future.

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