Grain Legumes Under Abiotic Stress:

Yield, Quality, Enhancement and Acclimatization

EDITOR
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CHAPTER 11

WEED DYNAMICS AND CONTROL IN LEGUMES UNDER CHANGING CLIMATE

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INTRODUCTION

Legumes are effective contributors to soil health through their nitrogen fixation potential leading to improved crop yields (Esfahani et al., 2016). Further, the role of legumes in global food security is of immense importance. However, productivity of legumes is severely hampered by several biotic factors including those of weeds.

Recently, the climatic changes particularly global warming and rise in atmospheric carbon dioxide concentrations are seriously affecting the crop production and pest management (Jabran et al., 2020). Climate change is likely to impact the growth and control of weeds (Jabran et al., 2015; Jabran and Dogan, 2018,2020). Climate change has both the positive and negative sides for prevalence and control of weeds in legumes. For example, temperature changes may lead to floral composition shifts in various agroecosystems in high altitude and latitude environments, and this weed floral change may come in favor of weeds sometimes and in favor of crops other times. Similarly, changes in temperature and humidity may alter weed seed dispersal (Amare, 2016). This chapter highlights the major weeds and weed dynamics of legumes, critical weed interference periods in legumes, impact of changing climate on the weed dynamics and strategies that may be adapted for weed control in legumes under changing climate.

LEGUMES AND WEED DYNAMICS

Weed Dynamics in Chickpea (*Cicer arietinum* L.)

Chickpea is one of the most valuable legume crops because of its rich protein contents (18-30%). The crop plays an important role in human diet (Maghsoudi and Eizadi-Darbandi, 2021). This crop is a weak competitor against weeds due to low height and slow growth and may face 40 to 90% yield reduction. Some of the common weeds of chickpea include *Chenopodium album* L., *Argemone mexicana* L., *Cyperus rotundus* L., *Carthamus oxyacantha* M. Bieb., *Cenchrus ciliaris* L., *Asphodelus tenuifolius* Cav., *Polygonum* spp., *Fumaria* spp., *Lathyrus* spp., *Vicia sativa* L., *Cynodon dactylon* (L.) Pers. and *Cirsium arvense* (L.) Scop. (Khan et al., 2018). *Lolium rigidum* Gaudin is a highly challenging weed in chickpea production in Australia (Mahajan et al., 2019). *Avena fatua* L. and *Artemisia Ludoviciana* Nutt. also cause serious problems in chickpea in Australia. *Avena fatua* and *L. rigidum* originally affect wheat (*Triticum aestivum* L.) production but also have become common weeds of chickpea (GRDC, 2018; Mahajan et al., 2019). Other common broadleaved weeds in Australia which take advantage of the poor competitive ability of chickpea are *Argemone ochroleuca* Sweet, *Emex australis* Steinh., *Silybum marianum* (L.) Gaertn., *Fallopia convolvulus* (L.) Á. Löve, *Polygonum aviculare* L., and *Cyclospermum leptophyllum* (Pers.) Sprague (GRDC, 2018).

Chenopodium album, C. murale L.*, Fumaria indica* (Hausskn.) Pugsley*, Rumex dentatus* L.*, V. sativa* and *A. fatua* were listed as major weeds in Punjab, the region of Pakistan with highest chickpea

production (Abbas et al., 2016). Other important weeds of district Lakki Marwat, NWFP in Pakistan are *Asphodelus tenuifolius* L., *Astraglaus* spp., and *Medicago denticulate* Willd. (Hassan et al., 2010). In Turkey, some of the chickpea (and wheat) weeds are *Veronica hederifolia* L., *C. datcylon* and *Avena sterilis* L. (Üstüner, 2016).

In Iran, chickpea production is faced with the daunting challenge of dealing with various broadleaved weeds including *Sinapis arvensis* L., *Carthamus oxyacanthus* M. Bieb., *Galium tricornutum* Dandy, *Lepidium draba* L., *Conringia orientalis* (L.) Dumort. and *C. arvensis* (Shahbazi et al., 2019). Meanwhile, *Thlaspi arvense* L., *Anthemis cotula* L., *C. album, Salsola tragus* L., *Kochia scoparia* (L.) Schrad. and *Lactuca serriola* L. are the common broadleaved weeds affecting chickpea production in the USA (Singh and Diwakar, 1995; Boydston et al., 2017). Similarly, chickpea production in Mexico, North America is affected by weeds such as *C. arvensis, Chenopodium* spp., *Melilotus indica* (L.) All., *Phalaris minor* Retz., and *Polygonum* spp. (Singh and Diwakar, 1995).

Weed Dynamics in Lentil (*Lens culinaris* Medik.)

Lentil is one of the most common legume crops that provide major protein and fiber for human consumption (Yang et al., 2021). Weeds cause a major limitation in lentil growth and yield due to its slow early growth, short stem and low pod positioning (Maghsoudi and Eizadi-Darbandi, 2021). Major weeds of lentil include *S. arvensis*, *Triticum* spp., *Convolvulus arvensis* L., *Vicia* spp., *Avena* spp., *Centaurea depressa* M. Bieb., *V. pyramidata* and *Fumria officinalis* L. (Tepe,

2014; Guncan, 2014; Kraehmer, 2016; Pala et al., 2018). The weeds of lentil seem to differ with location. *V. sativa* is commonly found to grow with lentils in Turkey and India. In a lentil weed survey in Sanliurfa, Turkey by Bukun and Guler (2005) *Galium aparine* L., *Hordeum spontaneum* K. Koch*, L. serriola, A. fatua, Scandix pecten-veneris* L.*, Isatis tinctoria* L.*, Salvia spinosa* L., *Orobanche aegyptiaca* Pers., *Matricaria chamomilla* L., and *Vaccaria pyramidata* Medik. were determined as important weeds having importance values of species scores higher than five. *Galium aparine and H. spontaneum* were also noted to be in high frequency and density. In addition, *S. arvensis, Ranunculus arvensis, Cephalaria syriaca* (L.) Schrad. Ex Roem. & Schult., *C. depressa, A. sterilis, Papaver* spp.*, Silene conica* L.*,* and *V. sativa* were reported in Diyarbakir, Turkey (Pala, 2019; Balli and Ozaslan, 2020).

Some common weeds of lentil in India *include C. dactylon, C. rotundus, Anagallis arvensis* L.*, Cannabis sativa* L.*, A. fatua, A. mexicana, C. arvense, C. arvensis, Fumaria parviflora* Lam.*, Parthenium hysterophorus* L.*, Lathyrus aphaca* L.*, M. indica, P. minor, Solanum nigrum* L. and *V. sativa* (Mahanta et al., 2003; Kumar et al., 2018).

Weed Dynamics in Faba Bean (*Vicia faba* L.)

Faba bean is a valuable legume species because of its wide range of uses i.e., food, feed and green manuring (Lavania et al., 2015). Weeds are major constraint in faba bean production and their unrestricted growth caused 80% yield reduction (Mohamed et al., 2004). *Echinochloa crus-galli* (L.) P. Beauv.*, F. convolvulus, Persicaria*

lapathifolia (L.) Delarbre*, C. album, Galeopsis tetrahit* L.*, S. arvensis, Veronica arvensis* L.*, Taraxacum officinale* (L.) Weber ex F. H. Wigg.*, Sonchus arvensis* L.*, Elytrigia repens* (L.) Nevski, *Plantago major* L.*, Equisetum arvense* L.*,* and *C. arvense* were reported in high density and frequency in Lithuania (Romaneckas et al., 2021).

In Mexico, some common broad-leaved weeds of faba beans were *P. aviculare*, *Glebionis coronaria* (L.) Cass. Ex Spach, *Vaccaria hispanica* (Mill.) Rauschert, *Papaver rhoeas* L. while *Bromus sterilis* L. and *P. minor* were two common grass weeds (Boutagayout et al., 2020).

Weed Dynamics in Field Pea (*Pisum sativum* L.)

Field pea is a legume that has a high-level protein and amino acids. Weeds are considered as one of the biggest constraints in its production as they cause a huge yield (77.2%) and quality reduction (Singh et al., 2016; Tripathi et al., 2001). In US and Canada, the reported weeds of importance are *A. fatua*, *S. arvense*, *Hordeum vulgare* (Harker et al., 2001) while in New Zealand, these are *Stellaria media* (L.) Vill, *Stachys* spp., *Spergula Arvensis* L.*, Achillea millefolium* L.*, Chenopodium* spp.*, Rumex* spp., *P. aviculare, T. officinale, Solanum* spp., *Trifolium* spp., *Polygonum convolvulus* L.*, G. aparine, V. sativa, E. repens* and *A. fatua* (Munakamwe and Mckenzie, 2008).

Chenopdium album, S. arvensis, S. media., Elymus repens (L.) Gould and *Trifolium* spp. are similarly found in high frequency among field peas in Finland (Salonen et al., 2005). Other weeds of high frequency

include, *Erysimum cheiranthoides* L., *F. convolvulus, F. officinalis* L., *Galium spurium* L., *Galeopsis* spp., *Lapsana communis* L., *Lamium* spp., *P. lapathifolia, S. arvensis, Tripleurospermum inodorum* (L.) Sch. Bip., and *Viola arvensis* Murray.

Weed Dynamics in Dry Bean (*Phaseolus vulgaris* L.)

Dry bean is a high value legume crop that is grown worldwide. Weed interference can cause a huge yield reduction and it varies according to weed type, weed density and environmental conditions (Harker and O'Donovan, 2013). *Amaranthus retroflexus* L., *C. album, Abutilon theophrasti* Medik., *Xanthium strumarium* L., *Polygonum persicaria* L., *S. arvensis* and *Cyperus esculentus* L. are listed as weeds of high frequency in Canada which is a major producer of dry beans (Soltani et al., 2012).

Studies on the effect of weed interference on the growth and yield of dry bean suggested that *C. album* and *A. retroflexus* were dominant weeds while *A. blitoides*, *C. arvensis*, *E. crus-galli*, *C. dactylon*, *S. arvensis*, *Setaria viridis* (L.) P. Beauv., *Malva neglecta* Wallr. and *P. major* are widely found weeds in dry bean field (Ghamari and Ahmadvand, 2012).

Weed Dynamics in Soybean (*Glycine max* (L.) Merr.)

Soybean is an important leguminous crop that is grown worldwide for both edible and fodder purpose. Weeds can cause 37% yield reduction which is much higher as compared to other pathogens and insect pests (Oerke, 2006). *Sorghum halepense* (L.) Pers., *E. crus-galli*, *Ambrosia*

artemisiifolia L., *Conyza canadensis* (L.) Cronq., *C. bonariensis* (L.) Cronq., *Bidens pilosa* L. and *Eleusine indica* (L.) Gaertn. are mostly found weeds of soybean crop in USA, Brazil and Argentine (Vivian et al., 2013). Moechnig et al. (2013) observed that *P. convolvulus*, *A. theophrasti*, *Amaranthus tuberculatus* (Moq.) Sauer, *C. album*, *Artemisia biennis* Willd., *Oenothera biennis* L., *Ulmus americana* L., *Equisetum hyemale* L. and *E. arvense* are important soybean weeds in South Dakota, USA. Increase in weed density (annual weeds) causes a significant yield reduction in soybean (Hazra et al., 2011).

CRITICAL WEED INTERFERENCE PERIOD

Tanveer et al. (2015) described three periods of weed interference as, 1. Period prior weed interference (PPWI) - it is the crop emergence time and weeds may grow with target crops without effect on productivity; 2. Total period of interference prevention (TPIP) - at this time, weed control must be done to ensure maximum crop yield; and 3. Critical period of weed interference (CPWI) - a delicate interval between PPWI and TPIP where lack of weed control or improper application of control methods may lead to yield losses.

Weed interference periods are dependent on a range of factors such as soil characteristics, environmental conditions, weed community, and the target crop hence an understanding of the weed interference periods are important to cost saving on herbicides use, effective weed control and reduced crop losses (Tepe et al., 2011). The onset of the critical weed interference period is determined by the weed density (Tanveer et al., 2015).

Critical weed interference in legumes differ with locations and weed species (Morishita, 2018). For instance, in the Mediterranean region, the critical period of weed interference is 50 to 69 and 28 to 33 days after emergence in chickpeas and faba beans, respectively (Frenda et al., 2013) making weed dynamic control in these legumes important during these periods. Although most of the farmers try to grow chickpea during early winter or autumn season, the suitable times for chickpea growing in Iran are autumn, spring or early winter. Because of a longer growing season in the winter planting, the yields obtained in winter are much higher than the spring planting. Importantly, the autumn planted chickpea crop faces a higher weed competition. Fedoruk et al. (2011) reported the critical weed interference period of soybean, chickpea, and field pea as 14-28 days after sowing.

In the USA, Morishita (2018) stated that the critical weed interference period of dry beans was five weeks to control annual weeds whereas control of *Solanum physalifolium* Rusby should be done in 6 to 9 weeks post emergence. Also, lentils, grown in Washington USA and Saskatchewan, Canada were more competitive against weeds in relation to those from Northeast Jordan (Smitchger et al., 2012; Fedoruk et al., 2011). Among the lentils of Jordan grown under similar conditions, the critical weed interference period is 12 to 14 weeks in Northeast differently from 7 to 8 weeks in Northwest (Morishita, 2018). With regards to seasons, lentils grown in the USA and Canada during the spring were reportedly of equal competitiveness as those grown in Turkey during winter (Tepe et al., 2005).

IMPACT OF CLIMATE CHANGE ON WEED DYNAMICS

Adaptation of weed to diverse range of environment and temperature due to their physiological plasticity in addition to high genetic variation as compared to legumes that have a lower competitive advantage with increased environmental stress indicated by changing climate (Amare, 2016). The impacts of climate change on weed dynamics includes their floral composition and distribution/population density, biomass, competitiveness against other crops, invasion, and management in agricultural systems.

Population Density

In agricultural cropping systems, the density of grown crops is kept constant according to plant population while the density of weed species varies with the degree of infestation and can be determined by richness of soil seed bank (Radosevich et al., 2007). Due to this variation, the competitive ability of weeds increases and in case of legumes, as they are already less competitive so weeds can easily infest in whole field.

Crop-Weed Competition

Competition between weeds and crops are mainly for space, light, water and soil nutrients. This complex crop-weed interaction was reportedly shifted in favor of some C4 weeds (e.g *C. album*) as against C3 weeds (e.g., *A. retroflexus*) with the elevation of CO_2 (Ziska, 2000). In addition, rising temperature reportedly increases competitive advantage of C4 weeds than C3 weeds (Tungate et al., 2007). Piao et al. (2019)

opines that temperature changes in addition to variation in phenology may disrupt food chain in an ecosystem.

Weed Invasion

Increased risk of weed invasion and ability to colonize more environments beyond the native range are likelihoods (Naidu, 2015) with extreme weather conditions which are typical of climate change. Rising CO_2 levels are reported to aid higher weed invasion (Ziska and George, 2004), in addition to the innately high reproducibility of weeds which is a major factor of their invasiveness.

WEED CONTROL IN LEGUMES UNDER CLIMATE CHANGE

The efficacy of weed management is also postulated to be changed along with the change in climate conditions (Jabran et al., 2020). Under climate change scenario, weeds germinate aggressively so more energy and labour-intensive practices are required for managing these weeds (Siddiqui et al., 2022). Both chemical and non-chemical methods are used for controlling weeds under climate change scenario.

Chemical Weed Control

Chemical weed control is an easier, efficient, cost effective and reliable method used for controlling all types (annual, biennial and perennial) of weeds. Under climate change conditions, the chemical properties and effectiveness of herbicide may change (Jabran et al., 2020). A study showed that the effectiveness of an herbicide was changed due to higher weed growth under climate change conditions (Bailey, 2004). Hence, it may demand to increase herbicide dose for obtaining proper weed

control as compared to normal conditions (Bailey, 2004). Change in temperature levels, CO_2 concentration, humidity, rainfall pattern and wind velocities may disturb the physiochemical reactions of herbicides and ultimately change the absorption, translocation and effectives into plants (Keikotlhaile, 2011).

Use of high potency herbicide can control the weeds effectively in soybean under climate change conditions (Jinger et al., 2016). For example, use of quizalofop-ethyl 50g/ha can control all grassy weed and chlorimuron-ethyl 6g/ha can control annual grasses, broadleaved weeds and sedges when applied 15-20 days after sowing. Spraying the legumes with paraquat at flowering stage reduced seed setting in weeds (McMurray, 2010).

Climate change also affects the herbicide application pattern i.e., foliar or soil applied by influencing the basic chemistry of applied herbicide. Soil temperature and moisture content can influence the efficacy of soil applied herbicides while atmospheric conditions can influence foliar applied herbicides (Jugulam et al., 2018).

Non-Chemical Weed Control

Following non-chemical methods can be used for effectively controlling the weeds in legume crops under climate change scenario.

1. Crop Rotation

It is considered as the most effective and convenient weed control method under climate change conditions without paying extra costs. Crop rotation encourages diverse weed flora rather than one or few

dominated species that favors diverse control methods of these weeds even under climate change scenario (Liebman et al., 2014). For example, when soybean was rotated with corn or wheat, a diversified weed flora was obtained that can be easily controlled by common control methods (Satorre et al., 2020). A modelling approach showed that mixed legume species increase soil organic matter and soil nutrient while their rotation control weeds and diseases and helps to overcome yield reduction under climate change conditions (Ndufa et al., 2009).

2. Growing of Climate Resilient Crop Varieties

Development and growing of new crop varieties that have potential to combat with climate change and different environmental stresses would be helpful in controlling weeds under climate change scenario (Vollmann et al., 2010).

3. Sowing Time

Early or late sowing of crop cultivars is also helpful in increasing crop competition with weeds. In soybean growing of late maturing cultivars discouraged seed production and weed seed quantity in *Ipomoea lacunosa* L. and *Sesbania exaltata* (Raf.) Cory by enhancement in competitive ability due to maintaining vegetative growth for a longer time (Bennet and Shaw, 2000).

In lentil, increasing seeding density helped in reduction of weed biomass and increasing of yield (Baird et al., 2009). Another study showed that increasing seeding density enhanced the competitive ability of lentils which increased the suppression effect of chemical

control while using in a moderate rate (McDonald et al., 2007). Other practices like crop rotation, tillage and late sowing could also help in improving herbicide efficacy in lentil crop (Dogan et al., 2014; Kayan and Adak, 2006). In grain legumes such as chickpea and lupin, trimming the weed heads that escaped from previous control method, considerably reduced weed seed production (Riethmuller et al., 2009).

CONCLUSION

Climate change and its impacts on crop pests including those of weeds are a reality of today. Use of a combination of chemical and non-chemical weed control will be helpful in controlling weeds under climate change. Breeding of new cultivars with enhanced weeds suppress ability would be a greater contribution towards weed management in various crops under the climate change scenarios. Prediction about the damages caused by weeds in future is also important for achieving sustainable weed management.

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