**Review: Use of Herbicides as Harvest Aids in Pulses**

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**ABSTRACT**

Pulses are leguminous crops which are harvested for their dry seeds as source of protein in daily meals. These crops include chickpea (*Cicerarientinum*L.), lentil (*Lens culinaris*Medik.), mung bean (*Vigna radiate* (L.) Wilczek), dry bean (Phaseolus vulgaris L.) and faba bean (*Viciafaba* L.) etc. Harvesting of pulse crops is more challenged due to their indeterminate growth habit that leads more green leaves, stems and tissues at the time of maturity. Unexpected rainfall at physiological maturity reduces seed quality. Pre-harvest herbicides accelerate harvesting in pulses which have uneven maturity or weeds problem. Most of the pulses required only 2 to 3 days for complete desiccation if herbicides are applied at proper time near harvesting. This review paper discusses the types of pre-harvest herbicides being used as harvest aid and the appropriate stage of pulse crop plants at which these herbicides return the most. Moreover the registered herbicides for pulse crops are also reviewed.

**KEYWORDS**

Harvest Aids; Legumes; Herbicides; Glyphosate; Paraquat

**INTRODUCTION**

Pre-harvest desiccation can minimize the exposure time of crop to abiotic factors (precipitation and relative humidity), after physiological maturity (Fipke et al., 2018). Seed development is a period from fertilization to maximum fresh weight accumulation. Maturation of seed begins at the end of seed development and continues until harvesting (Mehta et al., 1993). Physiological maturity is the developmental stage at which seeds achieved maximum vigor and viability. If seeds remain for longer period on mother plant after achieving physiological maturity, then seed may become hard, give off color and viability and vigor is decreased Indira, Dharmalingam (1996).

Harvesting of pulses is complicated due to the indeterminate growth habit that causes more green tissues at the time of harvest. Weeds also reduce harvest efficiency and lowers seed quality. Harvesting of dry plants reduces mechanical damage to seed and harvesting is done with speed. It also prevents spread of inoculum of disease Miller (2002). Field drying of seed is a common practice but chemical desiccants may advance the harvest date, eliminate seed losses and improve quality without affecting seed germination (He et al., 2015).

A good defoliant or desiccant herbicide should have controlled contact action. A contact herbicide has immediate local phytotoxic physical and chemical action on plant tissue and it is not translocated. A contact defoliant or desiccant should be safe to handle, minimum corrosive action on the equipment of application and be formulated easily according to the requirement Stahler (1953).

Pre-harvest desiccants are classified into two categories: those which have rapid drying action (24 to 72 hours) and those with slow drying action (7 to 10 days) requiring time between applications to harvest. The dinitro compounds (4,6-dinitro-o-secondary butylphenol and amylphenol) diquat, (1:1'- ethylene-2:2'-dipyridylium dibromide) and PCP (Pentachlorophenol) have rapid drying action which can permit harvesting after 24 hours of treatment when conditions are hot and dry. Most pulse crops require 2 to 3 days interval from application to harvest. Chemicals that show slow action are endothal (3,6-endoxohexahydrophthalic acid), magnesium chlorate and nitrogen solutions applied in water Furrer, Bovey (2014).

The use of herbicides as desiccants will encourage farmers to grow pulse crops because they hesitate due to problems of harvesting/ threshing and especially rainfall at physiological maturity. This review paper will enable the farmers to assess the suitable desiccant and suitable stage of application for pulse crops.

1. **LENTIL**

Lentil (*Lens culinaris* Medik.) is a diploid (2n=2x=14), self-pollinated, cool season grain legume (Rodda et al., 2017). It is an important legume crop due to its high protein and micro-nutrients rich seeds (Kumar et al., 2015). The major lentil producing countries are Canada, India, Turkey, Australia, USA, Nepal, China and Ethiopia Reda (2015), (Khazaei et al., 2016). Its production is ranked at 4th position in Pakistan after chickpea, mungbean and mashbean Anonymous1 (2016-17). Lentil is a restorative crop due to its nitrogen fixing ability. Its straw is also used for animal feed (Ghanem et al., 2015).

Lentil plants continue to flower until growth is terminated by drought, frost, heat stress or nitrogen deficiency Cessna (1990). Due to this reason lentil is usually cut and left to dry in a swath before final harvest. But during this drying period seed quality is deteriorated and chances of ascochyta blight infection increased Gossen, Morrall (1984). So to overcome this problem of uneven maturity and rapid crop desiccation pre-harvest desiccants are used Wilson, Smith (2002).

Herbicides registered for harvesting of lentil crop in Canada include: glyphosate, diquat, saflufenacil, flumioxazin, carfentrazone and glufosinate Risula (2014). Diquat, flumioxazin, glufosinate ammonium, and saflufenancil alone or in combination with glyphosate provide consistent desiccation of weeds (Soltani et al., 2013). Addition of a partner to glyphosate (450 or 900 g a.e. ha-1) tankmix when 80% pods have changed colour from green to yellow increased the rate of dry down in pod, stem and leaf by 10%, 15% and 17% respectively at 4 days after desiccant application and 17%, 14% and 20% respectively at 8 days after desiccant application (Soltani et al., 2013). Diquat application alone or in mixture with glyphosate showed consistent dehulling and increased milling recovery yield (Subedi et al., 2017).

**Figure.1** Increase of dry down by glyphosate **Figure.2** Increase of dry down by glyphosate plus tankmix partner plus tankmix partner

When diquat herbicide was applied to the lentil plants @ 2 L ha-1 then plants turned brown by the end of the second day of application (Tang et al., 1992).

**Figure.3** Diquat residues in lentil straw/chaff

Improper application timing of pre-harvest herbicides may reduce yield and quality, and leave herbicide residues in the seed. This can cause commercial issues in marketing of lentil. Application of harvest herbicides before 30% moisture content in lentil seed reduced yield and 1000 seed weight. And the seed residue level was exceeding of 2.0 and 0.03 mg kg-1 for glyphosate and saflufenacil respectively (Zhang et al., 2017). Desiccation with harvest aids is a most rapid method of moisture reduction in seed followed by swathing and natural drying. It does not effect on germination of seed and cooking quality when applied at physiological maturity but desiccation with diquat prolonged cooking time (Tang et al., 1992).

1. **CHICKPEA**

Chickpea (*Cicer arietinum* L.) is fifth most important legume in the world on the basis of production after soybean, groundnuts, beans and peas Cokkizgin (2012). India produces 68% chickpea of the world and it is mainly grown for local consumption Teshale (2015). It is ranked first production wise among legumes in Pakistan Anonymous1 (2016-17). It is an important source of carbohydrate, B-group vitamins, protein and certain minerals Cokkizgin (2012), (Oliveira et al., 2017). It is grown in 54 countries with 90% of its area covered in developing countries (Shanko et al., 2017).

When chickpea plants turned yellow, pods are matured, seeds changed their color and are detached from the pods (pods rattle stage) then this is very mature stage of the crop. At this stage delay in harvesting will result in darkening and staining of seed coats. As desiccant is applied at mature stage so reduction in days by the application of desiccant is lower as compared to in lentils or peas. At this mature stage an herbicide desiccant will not accelerate maturity but can be used as harvest aid to terminate the crop and burn down the immature weeds Anonymous2 (2017), (McVay et al., 2017).

Herbicides registered as pre-harvest aids for chickpea in Saskatchewan (Canada) are diquat and carfentrazone at the rate of 1.24 to 1.73 L/ha and 71.63 to 116.09 mL/ha respectively when plants have yellowed, pods are matured and seeds are detached from within the pods Anonymous2 (2017), (McKay et al., 2002). While pre-harvest desiccants which are used in Australia for chickpea are diquat, glyphosate and glyphosate plus metsulfuron. Diquat is applied @ 2-3 L/ha when crop has attained full maturity but it is not harvested for 3 days after application. Glyphosate is applied @ 0.68-1.8 L/ha when crop has attained physiological maturity and have less than 15% green pods and crop is not harvested within 7 days of application. Glyphosate plus Metsulfuron are applied @ 0.5-1.1 L/ha and 5g/ha respectively when crop has reached to physiological maturity and have less than 15% green pods and crop is not harvested within 7 days of application Anonymous3 (2017).

Pre-harvest desiccant application reduces the chance of re-flowering and re-shooting in response to early rain. It reduces the delayed crop maturity on heavy clay soils and it is also useful in implementing early harvest management. It is useful to increase harvest efficiency by reducing the problems related to green stems that causes uneven flow of material through the machine header, which enables drum speeds to be reduced, reducing the proportion of cracked or damaged grain in the sample Anonymous3 (2017).

The speed of dry down will be reduced with late maturity of chickpea, cooler conditions and shorter days late in growing season. However desiccant can still be useful to provide dry down of green plants in shorter time than if no desiccant is used Anonymous2 (2017), (McKay et al., 2002).

1. **DRY BEAN**

Dry bean (*Phaseolus vulgaris* L.) is the third most important food legume after soybean and peanut (Singh et al., 1999). It is grown on all continents of the world except Antarctica Gepts (1998). Its grains have 20-25% protein contents (Fageria et al., 1997). Its green pods are also consumed as vegetable (Laing et al., 1984). Dry bean is an important food legume for Africa, Central and South America and Asia (Fageria et al., 1997).

Dry bean seeds are matured when 80% pods have turned green to yellow, tan and purple or striped Wilson, Smith (2002). However due to indeterminate nature of the crop and variations within field, all the crop plants are not matured at the same time. Such variations within field can be reduced and weeds can be dried down that can stain dry bean grains during harvesting by using herbicides as harvest aids Wilson, Smith (2002).

Herbicides registered for dry bean in Ontario, Canada are glyphosate, Diquat, glufosinate ammonium and carfentrazone-ethyl (Ontario Ministry of Agriculture, Food and Rural Affairs, 2012). At 4 Days after Application (DAA) of glyphosate (450 or 900 g a.e. ha-1) and carfentrazone-ethyl alone or tankmix in combination with glyphosate did not impact leaf or stem dry down as compared to control. While glufosinate ammonium, Diquat, saflufenacil, and flumioxazin increased stem and leaf visual dry down (Soltani et al., 2013), (McNaughton et al., 2015).

Pre-harvest herbicides should not be applied to dry bean plants until at least 77 to 85% of the seed pods have turned yellow to avoid damage. Even the traditional methods of cutting and windrowing can reduce seed weight and germination, if harvested before maturity Wilson, Smith (2002).

1. **FABA BEAN**

Faba bean (*Viciafaba* L.) is an important legume crop being grown in diverse environments Toker (2004). It is an ancient crop originated in the Near East and is grown in Europe, North Africa, Middle East and China Li, Yang (2014). It is mainly used for feed and food but it also fixes the atmospheric nitrogen and adds that nitrogen into the soil. So it can improve and sustain the soil productivity (Hartmann et al., 1983), (Crepon et al., 2010), Kopke, Nemecek (2010).

In general faba bean plants mature in 110 to 130 days depending on environmental moisture conditions. When crop matures, the lower leaves of plant turned dark and dropped, pods turned black and dropped from bottom to top. Pre-harvest desiccants registered for faba bean are Carfentrazone-ethyl, Carfentrazone and glyphosate, diquat and glyphosate. Glyphosate is used as harvest aid at the rate of 889.2 grams of acid equivalent/ha and to control perennial weeds. It is sprayed when the seeds have less than 30% moisture contents, stems are green to brown, pods are yellow to brown and 80% to 90% leaves have dropped. Diquat is also registered for faba bean as desiccant @ 1.73 L/ha. It should be applied when plants are matured Fleury (2016), Anonymous4 (2017), Anonymous5 (2017). Paraquat can be applied @ 0.4 kg/ha when grains have 40% moisture contents with no side effects on grain yield (Jilani et al., 2012).

1. **MUNG BEAN**

Mungbean (*Vigna radiate* (L.)Wilczek) is most important summer legume. It is grown throughout the tropics and subtropics (Li et al., 2017). It is a short duration crop and can be grown in wide range of soils and environments (HanumanthaRao et al., 2016).The seeds and sprouts of mung bean are used as an excellent source of antioxidants in China, India, Bangladesh and South-east Asia. Mung bean sprouts are also used as salad vegetable by many countries (Li et al., 2017; Xue et al., 2016).It contains vitamin A (94 mg), iron (7.3 mg), zinc (3 mg), calcium (124 mg) and folate (549 mg) per 100 g dry seed. Usually it is used in split form (Dhal) and in many other food products (Rasul et al., 2012). It is also rich in digestible protein (24%), due to which it is used in cereal-based diets (Khattak et al., 2003).

Mung bean is ranked 2nd production wise in Pakistan after chickpea Anonymous1 (2016-17). It is considered as a “poor men’s protein”. The indeterminate flowering habit of mung bean and dry conditions followed by rain results in light green, brown, black and small dark green pods. Green or sappy plant parts of mung bean or weeds can also transfer their sap to newly harvested mung bean seeds. This can result in staining of seeds. So solution of all these problems is to spray desiccant when plants have reached to their physiological maturity. A thumb rule of accessing the physiological maturity is to split open a pod and turn it upside down. If all seeds with in a pod fall out then that pod is physiologically mature irrespective of the color of pod Anonymous6 (2017).

We have tested paraquat herbicide as harvest aid on mung bean at Nuclear Institute for Agriculture and Biology (NIAB) Faisalabad, Pakistan during 2016-2017. All plants became desiccated when paraquat is applied at the rate of 1 L/ha after 2 days of application. Further research is needed on the dose of different desiccants and its effect on quality parameters of mung bean.

1. **CONCLUSION**

Pre-harvest herbicides used for different crops are given in **table.1**. These herbicides should be applied when plants have reached to their physiological maturity to minimize the reduction in seed yield, seed weight, seed germination and seedling development. There are many other crops on which these pre-harvest herbicides can be used and their appropriate dose, time of application and resides level in seeds can be studied.

**Table.1:** Pre-harvest herbicides used for different crops in different countries.

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| **Crop** | **Herbicides** |
| **Lentil** | Diquat, glyphosate, saflufenacil, flumioxazin, carfentrazone and glufosinate @ 450 or 900 g/ha |
| **Chickpea** | Diquat @ 2-3 L/ha  Glyphosate @ 0.68-1.8 L/ha  Glyphosate plus Metsulfuron @ 0.5-1.1 L/ha and 5g/ha respectively |
| **Dry Bean** | Glyphosate @ 900 g/ha  diquat, carfentrazone-ethyl, glufosinate ammonium, flumioxazine and saflufenacil alone or in tankmix with glyphosate @ 450 or 900 g/ha |
| **Faba Bean** | Paraquat @ 0.4 kg/ha  Diquat @ 1.73 L/ha  Glyphosate @ 889.2 grams of acid equivalent/ha |
| **Mung Bean** | Paraquat and Glyphosate @ 1L/ha |

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