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Weed management in sugar beet: A review

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Abstract

Sugar is an essential commodity and an integral part of the food chain which is the cheapest source of energy. It plays a vital role in the development of taste, texture, colour and keeps baked goods soft and moist. Sugar beet ranks second as a sugar producing crop in the world. Weeds in beet crops reduce the yield in the field level as well as make the harvesting and processing difficult. The weed seeds in soil bank are detrimental as they germinate in subsequent crop cultivation. Weed control failure causes severe yield loss in sugar beet. However, several weed control measures along with herbicides provide a significant increase of average yield in sugar beet. It has become necessary to reduce the use of them in order to protect the human health as well as the other living organisms. For this reason, alternative ways of controlling weeds are being practiced all over the world. The efficient way of reducing the use of herbicides with the revaluation of agronomic techniques is replacing herbicide treatments. Thereby weed control combines herbicidal and non- herbicidal methods in an integrated manner. Basically, integrated weed control approach provides a potential reduction in weed population. However, this system is not efficient to manage weeds in larger-scale sugar beet production.

Keywords: Weed management, sugar beet, herbicide, sugar crop

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1 Introduction

Sugar beet (*Beta vulgaris* L.) is ranked as the second important sugar crop all over the world next to sugarcane (*Saccharum officinarum* L.) which belongs to the family Chenopodiaceae (Brar et al., 2015). Sugar beet is a temperate crop and its root contains a high amount of sucrose (Paul et al., 2019). Its life duration is short (5–6 months) and contains a high concentration of sucrose (14–20%) compared to sugarcane as sugarcane's life duration is long (12–14 months) with the low amount of sucrose (10–12%) (Ahmad et al., 2012; Paul et al., 2018). About 30% for human consumption sugar of the world is contributed by the sugar beet crop (Bairagi et al., 2013).

Weeds are noticed as one of the major yield obstructive factors (Oerke, 2006). Sugar beet is a slow-growing crop early in the season and thus in the field it seems to be a poor competitor with weeds (May, 2003). If immediate control measures are not employed in the sugar beet field, a severe competition occurs in the crop growing period thus resulted in full crop damage (Cioni and Maines, 2010; Kropff and Spitters, 1991). Particularly effective weed control is required up to the first 60 days after emergence which is the critical period of sugar beet (Gerhards et al., 2017). It has been reported that sugar beet root yields can be reduced by 26–100% when competition from annual weeds that are uncontrolled which emerges at 8 weeks of sowing or at 4 weeks of the crop attainment the 2-leaf phase (Rosso et al., 1996; Schweizer and Dexter, 1987). Scott et al. (1979) stated that weeds might decrease yields by about 1.5% Day-1 for the following 6 weeks when the sugar beet crop at the 4 to 6-leaf phase and therefore, weed removal from sugar beet crops is essential until the 8-leaf stage (Gerhards et al., 2017).

In the sugar beet field, herbicides application have been started from early 1950s as preliminary approach of weed control, although hoeing and hand weeding are still used in many areas in the world (Schweizer and Dexter, 1987). The limited use of herbicides has become a requirement in the 1990s to address ecological contamination and subsequently

Table 1. Common, scientific and family names of the most important problematic weeds in sugar beet†

Common name	Scientific name	Family name
Powell amaranth	*Amaranthus powellii* S. Wats.	Amaranthaceae
Common amaranth, redroot pigweed	*Amaranthus retroflexus* L.	Amaranthaceae
Common ragweed	*Ambrosia artemisifolia* L.	Asteraceae
Wild-oat	*Avena fatua* L.	Poaceae
Rape, wild buckweed	*Brassica napus* L.	Brassicaceae
Common lambsquarters, fat-hen	*Chenopodium album* L.	Chenopodiaceae
Canada thistle, creeping thistle	*Cirsium arvense* (L.) Scop.	Asteraceae,
Field bindweed	*Convolvulus arvensis* L.	Convolvulaceae
Jimsonweed, thorn-apple	*Datura stramonium* L.	Solanaceae
Barnyardgrass, cockspur	*Echinochloa crus-galli* (L.) Beauv.	Poaceae
Common couch, quackgrass, twitch	*Elymus repens*, *Agropyron repens*	Poaceae
Common clave, goosegrass	*Galium aparine* L.	Rubiaceae
Common sunflower	*Helianthus annuus* L.	Asteraceae
Kochia	*Kochia scoparia* (L.) Schrad	Amaranthaceae
Pineappleweed	*Chamomilla suaveolens*	Asteraceae
False chamomile, mayweed	*Matricaria camomilla*	Asteraceae
Pale persicaria	*Polygonum lapathifolium*	Polygonaceae
Ladysthumb, redshank	*Polygonum persicaria*	Polygonaceae
Groundcherries	*Physalis* spp.	Solanaceae
Annual meadow-grass	*Poa annua* L.	Poaceae
Knotgrass, prostrate knotweed	*Polygonum aviculare* L.	Polygonaceae
Smartweeds, polygonum	*Polygonum* spp.	Polygonaceae
Common purslane	*Portulaca oleracea* L.	Polygonaceae
Giant foxtail	*Setaria faberi Herrm.*	Poaceae
Yellow foxtail	*Setaria glauca* (L.) Beauv.	Poaceae
Foxtail, bristle-grass	*Setaria* spp.	Poaceae
Green foxtail, green bristle-grass	*Setaria viridis* (L.) Beauv.	Poaceae
Charlock, wild mustard	*Sinapis arvensis* L.	Brassicaceae
Hairy nightshade	*Solanum sarachoides* Sendtner	Solanaceae
Potato	*Solanum tuberosum* L.	Solanaceae
Perennial sow-thistle	*Sonchus arvensis* L.	Asteraceae
Johnsongrass	*Sorghum halepense* (L.) Pers.	Poaceae
Common chickweed	*Stellaria media* (L.) Vill.	Caryophyllaceae
Field pansy, field violet	*Viola arvensis* Murr.	Violaceae
Velvet leaf	*Abutilon theophrasti* Medic	Malvaceae

† Source: Modified from May and Wilson (2006)

Table 2. Effect of tillage in the preceding crops on the weed species occurrence in sugar beet†

Soil cultivation	Preceding crop	Weeds
Conventional tillage (>20–25 cm)	Sunflower, maize, soybean	*Abutilon theophrasti*, *Amaranthus* spp., *Ammi majus*, *Chenopodium album*, *Cyperus rotundus*, *Cyrsium arvense*, *Cynodon dactylon*, *Datura stramonium*, *Echinocloa crus-galli*, regrowth of sunflower, *Polygonum* spp., *Salsola Kali*, *Sorghum halepense*, *Xanthium strumarium*
Minimum tillage (15–20 cm)	Wheat, sunflower, soybean	*Alopecurus myosuroides*, *Amaranthus* spp., *Ammi majus*, *Chenopodium* spp., *Cirsium arvense*, *Cynodon dactylon*, *Fallopia convolvulus*, *Lolium* spp., *Phalaris* spp., *Polygonum aviculare*, *Sinapis* spp.
Direct drilling	Wheat, sunflower, maize, soybean	*Agropyron repens*, *Alopecurus myosuroides*, *Cirsium arvense*, *Convolvulus* spp., *Equisetum* spp., *Fallopia convolvulus*, *Phalaris* spp., *Picris echioides*, *Poa* spp., *Sorghum halepense*

† Source: Modified from Cioni et al. (1998)

to protect human fitness. By replacing herbicides with the adjustment of different management practices and limiting the herbicide doses, the decrease of the use of herbicides can be achieved. Thus, in the integrated weed management, weed control involved in a chemical method including other non-chemical approaches (Cioni and Maines, 2010). Therefore, the real weed management is very important for sustaining sugar beet production to mitigate sugar demand.

2 Weeds of sugar beet

There are 60 weed species detected as major infesting species among 250 weed species in sugar beet crop in the world. Of which approximately 70% are broadleaved and 30% are grass weeds (May and Wilson, 2006). The dicot weeds are more destructive compared to monocots (Zoschke and Quadranti, 2002; Roos and Brink, 1996). The most important dicot weeds of sugar beet growing areas from the families of Chenopodiaceae, Asteraceae, Brassicaceae, and Polygonaceae. Annual grasses are usually less competitive than annual broad-leaved (Schweizer and May, 1993). The most common annual broad-leaved weeds are *Amaranthus retroflexus*, *Chenopodium album*, *Matricaria recutita*, *Polygonum aviculare*, *Fallopia* (*Polygonum*) *convolvulus*, *Sinapis arvensis* and *Stellaria media*; annual grasses are *Echinochloa crus-galli*, *Poa annua* and *Setaria viridis*. *Chenopodium album*, a species under to the same family of sugar beet, is one of the common weeds in this crop. The common name, scientific name and family names of the most important problematic weeds in sugar beet are listed in Table 1.

3 Effect of weed on sugar beet yield

Weeds are the major enemies in sugar-beet cultivation in many countries in the world including Bangladesh. The sugar beet crop is relatively susceptible to the competition of weeds due to its slow initial growth. Weed has significant effect on yield of sugar beet. The mixed weed populations greatly reduced sugar beet yield to the extent that about 99% in control plots as compared to weed free plots (Tekleselassie and Yirefu, 2013). Besides, a yield loss of 50 and 75% occurred when weeding was delayed for 60 and 90 DAS. According to Salehi et al. (2007), weed infestation reduced beet yield by 92.9% and 61.2% in 1999 and 2000, respectively, as compared to weed free throughout the growth period. Compared to weed-free check the weed infestation decreased sugar yield considerably due to weed infestation and a decrease of sugar yield in season-long weed infestation was 84.87% and 62.1% in 1999 and 2000, respectively. The crop yield lost up to 100% due to severe weed-crop competition under limiting weed control or without control (Kropff and Spitters, 1991).

4 Effect of weed on sugar beet quality

Weed-beet competition does not affect impure substances such as potassium, sodium and amino nitrogen in sugar beet juice. Above ground weed biomass production influenced individual beet root weight. According to Longden (1989), there was no correlation found between weed-beet population and the sucrose concentration as well as potassium, sodium, amino nitrogen or invert sugars. However, a strong correlation found between root and sugar yields with weed-beet population. With the increasing densities of weed beet, root and sugar yields were gradually decreased. A negative relationship between weed-beet density and sugar yield was observed by Longden (1989), which shown that the higher the weed-beet density the lower the sugar yield. Seadh et al. (2013) reported that weed control treatment significantly influenced on total soluble sugar (TSS)%, sucrose% and apparent purity% in beet juice over weedy check.

5 Weed control in sugar beet

5.1 Cultural control

5.1.1 Crop rotation

Weed control should be considered over the whole rotation instead of a single crop to ensure the protection of one weed species in the field. The weed control through crop rotation schedule is imperative because of its minimum cost, highest effectiveness and without or minimum environmental risk. Mono- and dicotyledonous species should be included in the weed management programs where the crop less similar to weed species or where weed control is easy for example it is easier to control *equisetum* in sorghum, in maize or wheat stubbles than in sugar beet or soybean. If well scheduled, it can be essential to a significant decrease of the unruly modeled by target weeds. Three or four years of not guests *Cuscuta* spp. (Common dodder) crops-growing, such as maize, sorghum, soybean, wheat, can give a noble support to crack the problem (Cioni and Maines, 2010). Crop rotation can influence the growth of sugar beet by controlling the intensity of weed infestation and suppress the weed spectrum in the field (Cioni and Maines, 2010; Koocheki et al., 2009). Crop rotation influence the stability of beet yield and quality was reported by Götze (2017).

5.1.2 Cover crop or mulching

Addition of cover crops into a sugar beet rotation is very typical (25% of sugarbeet area) in some countries (Merkes et al., 2001). In autumn, cover crops struggle with weeds for water, space, light, and nutrients and subsequently suppress weeds during their growth periods (Brust et al., 2014; Kunz et al., 2016) and as mulch in spring (Campiglia et al., 2015). Commonly used cover crop species in sugar beet fields are mustard (*Sinapis alba* L.), phacelia (*Phacelia tanacetifolia* Benth.) and radish (*Raphanus sativus* var. *oleiformis* (Stokes) Metzg.) (Petersen, 2004). By these rapid growing cover crops weed suppression is effectively occurred in field as light intensity reduced (Auler, 1998). Additionally, allelopathic properties of, some cover crops can suppress the weeds by releasing allelopathic ingredients into the environment (Kelton et al., 2012; Kunz et al., 2016). Secondary metabolites, glucosinolates are the representative of the family Brassicaceae (Fenwick et al., 1983). Isothiocyanates as degradation materials from glucosinolates are biologically active and can hamper weed sprouting (Al-Khatib et al., 1997). Though, this issue is important while the cover crops incorporated into the soil to prepare green manure (Petersen et al., 2001).

5.1.3 Tillage

Weed flora present in sugar beet farms can be changed by the reduction of tilling depth in the soil during land preparation. Cioni et al. (1998) observed that weed species configuration in sugar beet field varies due to different tillage system (conventional tillage, minimum tillage and direct drilling) of previous crops. The impact of tillage on weed flora configuration was not detected in case of annual weeds which are very problematic to control in sugar beet, while Polygonaceae, Gramineae and perennials were preferred by minimum tillage (Table 2). The minimum tillage could lead to increase in not only perennials and gramineae but also the Compositeae weed species (Table 3)

5.2 Mechanical control

Mechanical control removes weeds substantially by uprooting, chopping up the whole plants or untying weed stems and leaves from their roots. The unintentional spread of perennial weeds, through splitting up and dispersal roots, rhizomes, stolons and tubers which will again produce up into a new weed is another drawback (Cioni and Maines, 2010). To allow the use of cultivation equipment, wide distances between sugar beet rows is required. Based on the growth phase of the crops some precise farming tools should be used to escape crop injury in the field. For high effectiveness and crop care, the timing of mechanical farming is very important. For example, damp soil conditions never permit the use of hoeing machines even the effectiveness is reduced due to regrowth of the weeds in this condition. Harrows as mechanical weeder can be used also in the rows and harrows must not be used between emergence of the coleoptile from the seed and 2-leaf stage of the sugar beet. There are certain tools used in hoeing machines which remove weeds from the sugar beet rows namely finger weeders or a torsion weeder (Petersen, 2004). As a consequence, removal of weed by hand is quiet essential. Based on the weed outbreak and field situations there are about 70-300 hr ha^{-1} are required to effectively removal weeds in the row by hand. Hand weeding is very costly in case of industrial countries although now-a-days hand weeding is partial to very precise weed problems (e.g., weed beets). Hand weeding is fairly common in countries wherever labor is inexpensive than the use of herbicides (e.g., Turkey and the countries of the former Soviet Union) (Petersen, 2004). Most of the sugar beet growing countries tractor-mounted hoes is very vital to destroy weeds between sugar beet rows. Tractor hoes are used where herbicides have been sprayed in bands over the rows or to control difficult weeds in case of perennials or some weeds are too far advanced to be properly controlled by the herbicide (Cioni and Maines, 2010). Tractor hoes works greater in arid land as the soil is friable and as less re-rooting of the weeds while sharp tine weeders work properly when the soil is wet. The weeds can easily eliminate under moist conditions from the soil although monocot weeds can easily re-root under wet conditions (Jones et al., 1996).

5.3 Chemical control

Broad leaved weed species are the utmost competitive annual weeds. During midsummer, these weeds frequently raise to a height 2-3 times than that of sugar beet. In crop field, weed control is done by herbicides because chemical control is efficient and easily applicable (Lodovichi et al., 2013). Tank mixes of various herbicides are usually used to offer a wide range of weed control (May and Wilson, 2006). Chemical method of weeds control is the most vital ways of weed management in sugar beet farm (Table 4).

5.3.1 Pre-sowing and pre-emergence herbicides

Pre-sowing and pre-emergence herbicides are presently suggested in sugar beet fields to weed control. The pre-sowing is the non-selective contact herbicides that are recommended to destroy weeds before the crop appears while pre-emergence is the remaining soil-applied herbicides which are applied pre or post sowing. Non-selective herbicides prior to sugar beet germination, the main advantage of is that almost all the appeared weed species, including weed beet, are controlled. Paraquat, glyphosate and glufosinate-ammonium are the main contact herbicides that are used round the world (Cioni and Maines, 2010). Soil applied residual herbicides decrease the number of weeds which appear with the crop and it often sensitizes fighters to succeeding post-emergence sprays (Duncan et al., 1982; Cioni et al., 1991; Zanin et al., 1996). Pre-emergence herbicides

Table 3. Spreading of weed species related to the time duration of minimum tillage†

Biological group	Species	Years of minimum tillage§		
		1st	2nd	3rd
Geophyte	*Agropyron repens*	0	0	++
	Cirsium arvense	+	0	+++
Hemicryptophyte	*Picris echioides*	+	0	+++
	Taraxacum officinale	0	0	++
Therophyte	*Alopecurus myosuroides*	++	++	+++
	Conyza canadensis	0	0	++
	Daucus carota	0	0	+
	Lolium multiflorum	0	0	++
	Poa annua	+	++	++
	Senecio vulgaris	+	0	++
	Sonchus spp.	+	+	++++
	Veronica persica	+	+	++

† Source: Cioni et al. (1998); § 0 = not present, + = only presence, ++ = low spread, +++ = medium spread, ++++ = high spread

reduce weed population, complement subsequent post-emergence uses as well as offer certain flexibility with timing and choice of post-emergence treatments and so they are vital for the common of sugar beet growers (May and Hilton, 1985; Ansaloni, 1990). The increased consistency and previous post-emergence use of low dose sprays permitted the pre-emergence herbicides for broad-leaved weed management to be applied at lower doses than before used (Cioni, 1997). The common pre-emergence residual broad-leaved herbicides applied in sugar beet crops are chloridazon, clomazone, cycloate, ethofumesate, quinmerac, lenacil, metamitron, and metolachlor. To control grass weeds, herbicides that may be used before sowing are cycloate, dalapon, EPTC, metolachlor, TCA and tri-allate. However, these graminicides, particularly dalapon and TCA, though usually inexpensive, that are abundant less probable to reason crop injury, have been changed in many countries by judicious post-emergence graminicides (May and Wilson, 2006).

5.3.2 Post-emergence herbicides

Post-emergence herbicides are used for controlling weeds mainly for broad-leaved and grasses. A large amount of products and tank mixes are existing in post-emergence herbicides for control broad-leaved weeds such as chloridazon, clopyralid, ethofumesate, lenacil, metamitron, desmedipham, endothal phenmedipham and triflusulfuron-methyl (May and Wilson, 2006). Cioni and Maines (2010) reported that since sugar beet herbicides have enough residual activity to control the weeds although tank mixes of various herbicides are frequently used to deliver a broad range of weed control. Increase the efficacy of herbicides the spray additives are used to improve the contact of spray droplets on sugar beet leaves. When weeds and crop both have waxy leaves then spray additives are advantageous, especially under dry conditions. Adding an oil additive is recommended in many countries as post-emergence treatments although the main spray additives used in sugar beet crops are established on mineral or vegetable oils, tallow amines and wetters. Most of the post-emergence graminicide should be applied at a comparatively later phase of crop growth to offer adequate time to growth based on target (Cioni and Maines, 2010). Post-emergence herbicide could be applied in a low-volume and low-dose for controlling of broad-leaved weeds (Candolo, 1988; Muchembled, 1989; Balsari, 1996) while conventional doses of active ingredient are reduced by two-thirds. Balsari and Airoldi (1993) noticed that a upright spray was ensured by the little spray volumes shared with nozzles that produced relatively fine spray droplets to exposure of plants that apparently an economic weed control to the growers. Spraying to cotyledon-stage weeds is vital for the success of the method. So, in European countries the micro-rate system is widely acceptable (Cioni and Maines, 2010).

5.4 Biological weed control

Biological weed control is a process of controlling weed by the use of microorganisms to suppress weed in the crop field. Biological control of weeds is done by traditional method and augmentative (bioherbicide). The traditional method introduced external control agents while augmentative approach indicates the manipulation of microorganism that already exists in the ecosystem. Smith (1986) noticed some fungal pathogens of weeds namely; *Col-*

Table 4. Herbicides used in sugar beet production and their effects on sugar beet and weeds[†]

Herbicide	Mode and site of action	Sugar beet and weed injury symptoms
Pre-plant, applied post-emergence to weed before crop emergence		
Glufosinate-ammonium	Inhibition of glutamine synthetase	Plant foliage, especially new growth will turn yellow then brown
Glyphosate	Inhibition of EPSP synthetase	–
Pre-plant incorporated, pre-emergence		
Cycloate	Lipid synthesis inhibition	General stunting, crinkled, fused leaves. Shortened leaf mid-vein
Ethofumesate	Inhibition of cell division by a reduction of photosynthesis and respiration	–
Lenacil	Photosynthesis inhibition	Initial yellowing of leaf vein, injured plant tissue turns brown
Metolachlor	Shoot inhibition	Initial yellowing of leaf margin, affects older leaves, injured plant tissue turns brown
Metamitron, Chloridazon	Photosynthesis inhibition	
Quinmerae	Auxin activity. This in turn stimulates the production of ethylene	Inhibition of root growth, stunting of the shoot, epinasty and anthocyanin-coloration of the leaves
Post-emergence		
Clethodim, Fluazifop-P, Propaquizafop, Quizalofop-P	ACCase inhibition	Yellowing (chlorosis), browning of leaves emerging from grass whorl
Triflusulfuron-methyl	ALS-AHAS inhibition	General stunting, yellowing of leaves at the growing point
Clomazone	Carotenoid biosynthesis inhibition	Blanching of leaves. Susceptible species emerge but are devoid of pigmentation
Clopyralid	Growth regulator—synthetic auxin	Stem elongation, twisting, leaf cupping
Chloridazon, Lenacil, Metamitron, Phenmedipham	Photosynthesis inhibition	Initial yellowing or brown spotting on leaves, browning of leaf margins
Ethofumesate	Inhibition of cell division by a reduction of photosynthesis and respiration	–
Desmedipham	Inhibition of the Hill-reaction (affects assimilation ability of the plant)	–

[†] Source: Modified from May and Wilson (2006)

letotrichum gloesporioides spp. *aeschynomene* for control of *Aeschynomene virginica* in rice and soybean, several fungi, bacteria and viruses are potential bioherbicides. Some fungal pathogens also showing potentiality to management of *Abutilon theophrastii*, *Chenopodium album*, *Datura stramonium*, *Echinochloa crus-galli* and *Sorghum halepense* in sugar beet field (Cioni and Maines, 2010). A biologically active natural product is the great source of lead molecules to develop pharmaceutical, insecticidal and fungicidal products. Commercial herbicides and natural phytotoxins show a remarkable degree of similarity. Most of the cases as sources of natural products of herbicides the microbial sources are used in the herbicidal industry (Duke et al., 1996). Although hundreds of compounds have been patented but only two, bialaphos and phosphinothricin are successfully popularized. The chemically manufactured Glufosinate (form of phosphinothricin), works directly on plants while bialaphos need to be converted metabolically into phosphinothricin by plants (Lydon and Duke, 1999). In sugar beet fields currently biological control or natural phytotoxins strategies are used to control weeds. Cioni and Maines (2010) noticed that weed control in sugar beet crops might be promising in the longer period using bio-herbicides.

6 Herbicide resistance in sugar beet

Most of the selective sugar beet herbicides have some influence on sugar beet growth where initial symptom shows on the leaves. Therefore, this lack of selectivity reduces yield in sugar beet (Petersen, 2004). Genetic modification technology (genetic engineering) that is tolerant to broad-spectrum herbicides that can change the short spectrum herbicides presently in use, has allowed the production of sugar beet. The two broad-spectrum herbicides namely glyphosate and glufosinate are showed tolerance to genetically modified sugar beet varieties (Marlander, 2005). Genetically improved herbicide tolerant sugar beet enhanced early season crop vigour which increases the crops capability to capture sunlight, increase the struggle with weeds and improve sucrose yield (Wilson and Smith, 1999). Due to reduction of phytotoxicity of herbicide in plants the crop yield increased upto 15% thus reduces expenses by about 15% (Kniss et al., 2003; May, 2003). Intensive use of more than one herbicide resilient crop might cause problems regarding outcrossing of resistance, choice of herbicide tolerant weeds and volunteer crops, surface water contamination, a move in weed flora, and injury to non-target plants by application herbicide drift (Hurle and Petersen, 2000; Petersen et al., 1998). Therefore to address the mentioned problems management techniques is required before herbicide resistant cultivars are extensively cultivated (Petersen, 2004).

7 Reducing the use of herbicides

7.1 Integrated weed management

It is a systematic approach of weed control involving the application of strategies, principles, practices, methods and materials in an integrated, compatible, environmentally sound and economic way to achieve optimum crop production. Conferring to Endure's definition, IPM (Integrated Pest Management) is a justifiable measure to manage pests through applying all techniques (cultural, biological and chemical) in a way that reduces economic, environmental and health hazards. Locally it is adapted because they contribute to reducing dependency on pesticide in crop production (Cioni and Maines, 2010). The real agronomic need is only to defend the crop during the critical stage of weed competition where weed able to cause yield losses and after which weed competition will no longer decrease crop yield (Zimdahl, 1988). Covarelli and Onofri (1998) reported that sugar beet field should be saved weed free from 15 to 40 days after germination. Herbicide fate, persistence and weed control timing should be chosen accordingly. More or less fifty to seventy percent yield loss occurred in sugar beet when weeding was delayed from 60 to 90 days after sowing. IWMS must be applied to reduce crop-weed competition, enhance crop production and net returns. To attain goals thresholds for target weeds and weed population necessity to be understood. There are many thoughts to be allowed in mind when causal threshold values including the impact of weeds on the yield and quality of the crop (Cousens, 1986). Therefore, the forecast of the effects of given weed population would assist the sugar beet growers in making assessments on the best level of weed control efforts in their crop fields.

7.2 Post-emergence additives spraying

The activity of active ingredients of a pesticide or herbicide can be modified by additives. These additives can ensure reduction of drift, uniform distribution, enhance effectiveness and increase safety use. Depending on composition and action mechanism the additives can be differentiated as surfactants and sprays (anionic, cationic, non-ionic, amphoteric), stabilizers (emulsifiers, dispersing agents, anti-flocculation, compatibility enhances), solvents, oils (paraffinic and vegetable), deposit enhancers (adhesives and film formers), foaming and antifoaming and buffering agents. There are plenty of experimental evidences reported on additives in phytotherapy (Mantey et al., 1989; Gauvrit, 1994; Müller et al., 2001). The opportunity to change the higher toxic products and increase the biotic action of some mixtures employed exploiting seed oil (e.g. rapeseed oil) and buffering agents (pH optimizers) were reported by Tugnoli et al. (2003). Organosiliconic surfactants contained at least 98% triloxane composite augmented triflusulfuron-methyl action haste and herbicide activity by approximately 11% on target weeds (Chiot and Lanza, 2008).

7.3 Intermittent spraying

Herbicide flow sprays maintaining a short duration break is known as intermittent or sporadic spray technique. Benefit of this recurring spread is occurred from active ingredient dispersal system in cuticles of crop as well as permit getting a short distance between drops (Bukovac and Petracek, 1993). Hence applying spray sporadically the drops are distributed homogeneously on the leaves and maintain more distance compared to traditional method. This new spray method has been established to decrease herbicide and pesticide dispersion by the cuticle of the leaves. This system gave the same recital in comparison with the standard method on different weeds for example *Alopecurus myosuroides*, *Capsella bursa-pastoris* and *Veronica* spp. with strong reduced (−48%) herbicide dose (Falchieri et al., 2008).

8 Conclusions

Production of food for ever increasing population is the most challenging work, whereas weeds show severe competition with the crops for various growth resources. Weeds cause root yield loss in sugar beet by 26–100%. Moreover crop yields are reduced by weeds nearly 1.5% per day. Besides reduction in yield, weeds also reduces the quality of produces and acts as alternate host for disease causing organisms and insect-pests. Though manual method of weed control is very common, it is cost intensive. Herbicides when applied alone may have limitation of resistance development and shift in weed flora etc. although it is economical. Hence, various weed management practices need to be integrated in an appropriate manner during critical period of crop-weed competition. Research on herbicide mixtures, post-emergence herbicides, management of parasitic weeds, weedy rice, weed competitive crop cultivars with acceptable yield potential, weed management in changing climate scenario and conservation agriculture, effect of herbicides on soil microorganisms, etc. need to be strengthened. Therefore, use of high efficacy herbicides in combination with cultural or mechanical method that means integrated weed management is effective and economical.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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