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Chemical management of parthenium: A review

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Abstract
Parthenium is an invasive weed which causes severe yield losses in different crops. Weed-crop competition is main factor. For better crop production, weed control beyond the thre should density level is key component of integrated weed management strategy. Use of synthetic herbicides is key component of weed management and is considered the most effective, time saving and economical way to control targeted weeds. The present review highlights the chemical management of most important weed Parthenium.

Keywords: parthenium, losses, weed-crop competition, chemical management

1. Introduction
Parthenium hysterophorus L. is member of family Asteracea. Parthenium normally germinate in spring and early summer and having the indeterminate growth habit, produces flowers and seeds throughout its life span and in autumn it dies away (Adkins *et al*., 1996) [1]. South America and Carribean is the origin of this weed and have invaded almost thirty countries of the world including tropical region of Africa, Australia and Asia (Nigatu *et al*., 2010) [22]. In Pakistan parthenium weed is spreading all over the country and considered as invasive weed. Local name of parthenium is gajar booti (Shabbir and Bajwa, 2007) [35]. Wiesner *et al*. (2007) [47] reported that in invaded countries parthenium has become a potential colonizer over railway roads, water channels, in field crops and grazing pastures in different growing conditions. Parthenium causes yield losses in maize, sorghum, sunflower, fodders and black gram (Parsons and Cuthbertson, 1992; Tamado *et al*., 2002; Njoroge, 1996; Vivek *et al*., 2008) [27, 41, 23, 46]. Profitable agriculture is based on the wise and economic weed management strategies which is possible by estimation of weeds population that cause appreciable yield losses (Deines *et al*., 2004) [9]. The use of herbicide is also key component of weed management (Torra *et al*., 2010) [44] which kills weeds in limited time but due to development of resistance in crop plants and environmental risk (Sanyal and Shrestha, 2009) [32]. It is not possible to rely only on herbicide, so there is a need to develop integrated strategies which reduce herbicide application and must be friendly to environment. Weed control beyond the threshould density level is a key component of integrated weed management program for good crop production (Moorthy and Das, 1998; Knezevic *et al*., 2002) [18,15] and level of threshould density may vary with weed species (Onofri and Tei, 2006) [26]. So the knowledge of threshould density of parthenium is may be helpful for weed management program. Weeds causes different loss at their different weed densities (Tamado *et al*, 2002; Safdar, 2015) [42, 31].

The use of herbicide is one component of weed management program and is considered the most effective, time saving and economical way to control targeted weeds in subjected ecosystem in spite of some environmental and quality concerns. The post emergence herbicides applied directly on leaf canopy of targeted weeds are absorbed by leaves, stems, roots and kill weeds but its absorption depends on several factors, droplet size, surface tension, drift etc. and in some cases cuticular surface of leaf tends to repel spray drop due to small spherical droplet size (Schonherr, 2006) [34] which ultimately reduces herbicide absorption and efficacy. The one aspect of integrated weed management program is the use of herbicide in integration with adjuvant to increase the efficacy and to optimize the dose of herbicide for foliar applied herbicides (Duke *et al*., 2002) [10]. The presence of parthenium weed causes yield reduction in different crops due to the joint effect of allelopathic inhibition and competition with the main crop for growth indicators. Weeds compete for moisture, lights, nutrients and space (Anderson, 1983) [3] and they also release phytotoxic chemicals known as allele chemicals from their living and dead body parts which have inhibitory effects on growth and yield (Zimdahl, 2007). The present review describes the losses and management of parthenium.

2. Weed-crop competition
Knowledge of weed-crop competition may be helpful to improve the performance of agronomic practices which are performed to manage the weed flora. Competitive ability of weed depends on density of weed, duration of competition and species of weed. Critical period of competition and critical threshold level are the two most important aspect of weed-crop competition. Economic threshold level (ETL) is the density or population of weed which cause a significant yield loss and control measure should be started at that level while critical period of competition (CPC) is the period during which the presence of weeds may cause a significant loss in yield of a crop (Nazir, 1994) [21]. Critical threshold

Level and critical competition period may vary with plant species. Weed competition for longer time during life cycle may cause more losses.

Different parthenium-crop critical competition periods have been studied for different crops. Previous studies show that 19-67 days are critical for pathenium-crop competition in sorghum (Sorghum *bicolor* L.), 30-60 days after sowing of arhar (*Cajanus cajan* L.) and 30-45 days for black gram (*Phaseolus mungo* L.) (Vivek *et al*., 2008) [46]. However, if parthenium is left uncontrolled for full season it may cause 40-97 % losses in grain yield of sorghum (Tamado *et al*., 2002; Tefera, 2002) [42,43], 33% and 67% reduction in grain yield of arhar and blackgram, respectively (Vivek *et al*., 2008) [46]. Channappagoudar *et al*. (1990) [7] reported that other weeds and parthenium affected the growth and yield components of sorghum. Presence of parthenium reduced grain yield (4.25 t/ha) than weed free control (6.45 t/ha) and presence of weeds other than parthenium reduced grain yield upto 5.21 t/ha than control (6.45 t/ha). Morales-Payan (2000) [19] reported upto 63% reduction in tomato plant yield and biomass when parthenium density was 0-6 plants m^{-2} but tomato plant height remains unaffected. Cumberland *et al*. (1971) reported that weeds compete critically and uptake maximum nutrients during 4-6 weeks of crop emergence in maize fodder so the controlling of weeds during this period increased the yield and yield components of maize. Lawrence and Sprague (2004) [17] also reported that the ETL of *Amaranthus radis* L. in maize was 0.3-1.4 plants m^{-2} and first 30-40 weeks after sowing of crops were critical and *Amaranthus radis* L. must be controlled at this ETL and during this competition period.

Singh *et al*. (2007) [37] reported that 30 plant m^{-2} caused the minimum loss in yield and suggested it as an economic threshold level of barnyard grass in rice. Vivek *et al*. (2008) [46] reported that critical period of weed competition periods in *Phaseolus mungo* L. (blackgram) was 30-45 DAS. Reduction in grain yield was observed if crop weed competition period was increased and a loss of 67% occurred in yield if full crop season competition was allowed.

Khan *et al*. (2013) [14] concluded that parthenium caused 40% yield reduction in crops, increased 21% cost of weeding in term of extra labor and 16 % reduction in quality of crop produce. Contrib *et al*. (2009) [8] observed negative correlation between density of *Trianthema portulacastrum* L. and growth (growth rate, relative growth rate, dry weight, leaf area index), yield parameters (pods/ plant, seeds/ pod, seeds/ plant, seed yield, net assimilation rate) and nutrient uptake (N, P and K). The maximum negative impact was observed at 200 plant m^{-2} of *Trianthema portulacastrum* L. Rosenbaum *et al*. (2011) [30] reported reduction in yield, biomass and nutritive value of fescue pasture (*Festuca arundinacea* L.) as densities of both weeds increased.

Vivek *et al*. (2008) [46] observed decrease in grain yield with increasing the duration of competition period and observed 33% reduction in grain yield when full season competition was allowed and concluded that 30-60 days after sowing was the critical competition duration period of weeds in arhar and crop should be weed free during this period.

Barroso *et al*. (2012) [4] observed the highest relative importance for *Parthenium hysterophorus* L. and critical period of weed interference was between phenological stage leaf two and leaf three stage of bean (*Phaseolus vulgaris* L.) Okafor and Zitta (1991) [25] described that fertilized sorghum was tolerant to weed loss at initial growth stage till two weeks with negligible yield loss but after that huge reduction in yield was observed when weeds allowed to compete for 2-7 weeks by reducing 1000 grain weight, number of grain per spike and spikelets per spike. Un-weeded sorghum showed a decrease in yield loss up to 65% in severe competition.

3. Chemical weed control

Effective and quick control of *Parthenium hysterophorus* L. is only possible by the application of herbicides. Parthenium is more susceptible to those herbicides which inhibit photosynthesis, amino acid synthesis and glutamine synthase as compared to herbicide which have other physiological action. Parthenium can be controlled by pre-emergence as well as post-emergence herbicide. Post emergence herbicides applied at rosette stage (initial stage) was more effective for its control (Reddy *et al*., 2007) [28]. Sharma (2003) [36] concluded from his experiment that in non-cropped area application of 1000 to 1500 g/ha of metribuzin have shown 100% control of parthenium as compared to equal dose of glyphosate which gave 50 to 60% control, while 2,4- D has given only 40% control when applied at the rate of 100 g/ha. Reddy *et al*. (2007) [28] clomazone and norflurazon applied as pre-emergence controlled the parthenium 100%, while fluometuron, metribuzin, diuron, flumioxazin, chlorimuron and quinclorac gave 96, 90, 87, 84, 77 and 67% parthenium control, respectively.

Robles *et al*. (2005) [29] reported that prosulfuron at reduced dose proved excellent and efficient weed control with 32 % overall cost reduction and 50% reduction in herbicide cost as compared to its standard dose and 31 % cost reduction as compared to dicamba standard dose. Tadesse *et al*. (2010) [39] compared the efficiency of atrazine (0.75 kg/ha) and pendimethaline (1.0 kg/ha) applied as pre-emergence for the control of parthenium in grain sorghum and reported that atrazine performed better as compared to pendimethalin and also increased 90.8% grain yield over weedy check. Khan *et al*. (2012) [13] evaluated the effectiveness of different herbicides (atrazine, bromoxinal+MCPA, glyphosate, S-metolachlor, metribuzin, triasulfuron+terbutryn, atrazine+s-metalachlor pendimethaline and 2,4-D @ 1.0, .80, 4.0, 1.92, 2.0, .30, 1.50, 1.50, 1.0 kg ha^{-1}, respectively) for the control of parthenium at two different growth stages (rosette and bolting stage) in non-cropped area. Glyphosate and metribuzin gave better results than remaining herbicides. At rosette stage glyphosate gave 96% mortality of parthenium followed by metribuzin with 87% mortality after four weeks of treatment. While at bolting stage 91% and 75% mortality was observed in case of glyphosate and metribuzin, respectively after four weeks of application. Tamado and Milberg (2004) [41] compared the chemical control (2,4-D @ 1440 g a.i. ha^{-1}), ecological control (growing of cowpea as intercrop) and cultural control (hoeing) for the control of parthenium and they reported that cultural control was the best control measure as it improved the yield as well as soil physical properties (porosity, bulk density etc.) and it was followed by 2,4-D with inconsistent parthenium control because weeds have emerged at later stages from the soil seed bank and there was no increase in grain yield of sorghum.

Safdar (2015) [31] conducted research trial for screening different herbicides for the control of parthenium in maize. The herbicide tested were atrazine @ 360 g a.i. ha^{-1}, atrazine + *s*-metolachlor @ 720 g a.i. ha^{-1}, atrazine + nicosulfuron 385 g a.i. ha^{-1}, dicamba @ 304.5 g a.i. ha^{-1}, bromoxynil + MCPA + metribuzin @ 470 g a.i. ha^{-1} and reported that bromoxynil + MCPA + metribuzin @ 470 g a.i. ha^{-1} proved better and showed 100 % mortality rate and lowest biomass of parthenium and other all crop parameters were also higher in this treatment. This treatment was followed by the application of dicamba @ 304.5 g a.i. ha^{-1}.

4. Use of herbicide with adjuvant combination

An adjuvant is a chemical with herbicide formulation or mixed in spray tank prior to spray the crop to enhance the performance of herbicide and application characteristics (Tu and Randall, 2003) [45]. So adjuvant is defined as "an ingredient that modifies or improves the action of principal active compound". Adjuvant may be antifoaming agents, compatibility agents, buffering agents, drift control agents, organosilicon and nitrogenous fertilizers (nitrate and ammonical). These compounds increase the amount of herbicide absorbed into the plant. Now a day's adjuvants are frequently used in agriculture to improve the performance of herbicide and most common fertilizer being used as adjuvant is ammonium sulphate. The combination of herbicide and adjuvant is used for the control of weeds. Adjuvant and herbicide combination enhance the selectivity and performance of mixture against broad leaf weeds (Scherb *et al*., 2000) [33]. Lajos *et al*. (2000) [16] concluded that the reduced dose of chlorifazon, triflusulfuron, metamitron can be applied for the control of five weeds species in sugar beet if herbicides are used in combination with white oil adjuvant @ 1 L ha^{-1}. Bunting *et al*. (2004) [6] studied the effect of several adjuvants on the performance of formasulfuron in green house and in field condition and concluded that addition of methylated seed oil in herbicide had great impact on weed controlling efficiency of formasulfuron in green house condition. In field condition addition of nitrogenous fertilizer improved the performance of herbicide and combination of methylated seed oil + nitrogenous fertilizer proved to be best against annual weeds. Nalewaja *et al*. (2007) [20] evaluated the efficiency of glyphosate, isopropyl amine, 2, 4-dimethyle amine, bentazon sodium and dicamba sodium sprayed alone and in combination with adjuvants. They reported increase in weed controlling efficiency of herbicides when sprayed in combination with citric acid, ammonium sulphate (adjuvants). Norsworythy *et al.* (2007) [24] also studied the effect of ammonium sulphate as an adjuvant on the weed controlling potential of glyphosate and glyphosinate in soybean (*Glycine max* L.) crop. They reported increase in weed mortality rate and decreased weed biomass when combination of herbicides (glyphosate, glyphosinate) and ammonium sulphate was applied.

Idziak and Woznica (2008) [11] checked the efficacy of full (1.5 L ha^{-1}) and reduced dose (1.0 and 0.75 L ha^{-1}) of callisto 100 Sc (mesotrion) with and without adjuvant combination (methylated seed oil, parafine oil, ammonium nitrate) for the control of barnyard grass and lamb's quarter and reported 97-100 % control of lamb's quarter with and without adjuvant. Phytotoxicity of callisto 100 Sc (mesotrion) against barnyard grass was increased due to adjuvant and herbicide combination also increased yield of maize when reduced dose was combined with adjuvant as compared to applied alone. Tahir *et al*. (2011) [40] evaluated the effect of manual hoeing and full and reduced dose of herbicide (foramsulfuron + isoxadifen + isosulfuronmethyl sodium) alone and in combination with urea as an adjuvant for the control of weeds of maize and reported that weeds biomass and density recorded at crop harvest was minimum where full dose of foramsulfuron + isoxadifen + isosulfuronmethyl (228.75 g a.i. ha^{-1}) along with 3% urea solution was applied. Amiri *et al*. (2013) [2] conducted a field experiment to evaluate the performance of different herbicides alone and in combination with adjuvant { bentazone (1920 g a.i. ha^{-1}), bentazone (1440 g a.i. ha^{-1}), bentazone (1440 g a.i. ha^{-1}) + an adjuvant (tween 80), bentazone (1440 g a.i. ha^{-1}) + an adjuvant (ammonium sulphate), imazethapyr (100 g a.i. ha^{-1}), imazethapyr (75 g a.i. ha^{-1}), imazethayr (75 g a.i. ha^{-1}) plus an adjuvant (ammonium sulphate)} for the control of weeds of new sainfoin (*Onobrychis sativa* L.), a forage crop in Iran and observed that low dose of bentazone (1440 g a.i. ha^{-1}) in combination with adjuvant (ammonium sulphate, tween 80) was found more efficient for the control of noxious weed of sanifoin forage. However due to loss in biomass of sainfoin forage after these treatments application, imazethapyr (75 g a.i. ha^{-1}) proved to be the best treatment to control and improve yield of newly planted sainfoin forage. Javaid *et al*. (2012) [12] evaluated the efficacy of different herbicide (carfentrazone-ethyl, fluroxypyr + MCPA, bromoxynil +MCPA, tribenuronmethyl, thifensulfuron-methyl) against *E. spinosa* at their recommended dose alone and with the combination of herbicide half dose + adjuvant (fatty alcohol ethoxylate and alkyl ether sulphate sodium). They reported that addition of adjuvant in herbicide significantly increased the efficacy of herbicide and increased the weed mortality rate and weed biomass was low where herbicide half dose and adjuvant combination was sprayed. The weed mortality rate and biomass in herbicide and adjuvant combination was similar to the full dose alone of application of herbicide except carfentrazone-ethyl. Bekeko (2013) [5] reported that urea and common salt can be used as adjuvant with glyphosate which enhanced the activity of glyphosate in non-cropped area. He achieved full control of parthenium at early growth stage when 150 g urea and 150 g common salt was mixed with 3 L ha^{-1} of glyphosate but the same combination was not so good when applied at the later stage of parthenium. Singh *et al*. (2004) [38] also conducted an experiment to check the efficacy of glyphosate alone and in combination with adjuvant (MON 0818) for the control of parthenium. They reported that combination of herbicide @ 2.7 kg ha^{-1}with adjuvant increased the efficacy of glyphosate and gave quick control of parthenium as compared to full dose (5.4 kg ha^{-1}) of glyphosate.

5. Conclusion

Parthenium causes high yield losses in agronomic crops specially in sorghum. It not only competes for food and space but also reduced its quality and growth. Management through synthetic chemicals and as combination with different adjuvants is suitable and most economical way.

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