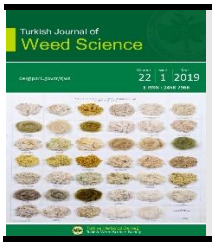

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Derleme Makale / Review Article

Sustainable Weed Management in Maize (*Zea mays* L.) Production: A Review in Perspective of Southern Asia

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ABSTRACT

Weed species and maize crop strongly compete for nutrients, water, space and light for their growth and development. There is a strong correlation between weed population and maize yield. Weeds crop association, critical period of crop-weed competition, methods of weeds control, herbicide tolerant maize cultivars and losses due to weeds and economics of weed control in maize are discussed in this review. The output of different research works clearly indicated that weed infestation led 20-80% reduction in maize yield. The critical period of crop weed competition varies from 2 to 7 weeks after crop sowing, with the most critical competition between 4-7 weeks after sowing. Weed control measures should be taken during this period to minimize the yield loss of maize and increase the water and nutrient use efficiency. Herbicides are popular and widely used measures to control weeds in maize production systems, but several studies have shown their negative environmental consequences. Single approach-based weed management system becomes inefficient against maize weeds. The integrated weed management (IWM) system is recommended to reduce the use of herbicides for its sustainable production.

Key Words: *Maize, weeds, herbicides, economics, integrated weed management, sustainable production*

INTRODUCTION

Maize (*Zea mays* L.) is believed to be originated from Mexico and Central America (Schnable et al., 2009). Now it is the highest produced staple cereal followed by wheat and rice in the world with production of 1033.74 million metric tons from 197 million ha (Statista, 2018; FAOSTAT, 2017). Weed infestation is a potential problem to realize higher yield of maize around the globe as well as in south Asia. Weeds not only decrease crop yield but also harbor insects, pests and diseases. In some cases, they serve as an alternate host for these pests (Letourneau, 2011). In organic farming, the weeds are managed by applying mulches, cultural, physical, mechanical and chemical methods as components of integrated weed management (IWM) that helps to promote crop yield (Karlen, 2007). Weed must be properly managed to avoid economic losses in crop production. Initial 6 weeks after sowing (WAS) are found very susceptible to weed infestation in maize, significantly decreasing final grain yield (Das et al., 2016). Weed infestation decreased maize grain yield by 58-62% and 67-79% during winter and summer seasons, respectively, in Sudan (Mukhtar et al., 2007).

Crop weed association

Among mentioned weed species, the most abundant ones were *Amaranthus spinosus*, *Bidens pilosa*, *Commelina benghalensis*, *Mariscus alternafolius* and *Cynodon dactylon found at Cameroon* (Ndam et al., 2014). Fongod (2004) also concluded similar findings. Bharati (2016) also observed that *Commelina benghalensis, Mariscus alterfolius* and *Cynodon dactylon* showed dominancy in maize field infestation at Orrisa, India.

Table 1. Percentage contribution of plant families in the formation of weed flora in maize field in South West region of Cameroon and Pokhara, Nepal

S.N.	Scientific Name	Cited Author's Name	Family	Weed family contribution (%)	Location
1	*Acanthus montanus* (Nees) T.Aders *Lindernia crustaceae*	Ndam et al., 2014	Acanthaceae	4	South West region of Cameroon
2	*Cyathula prostrate* (L) Blume *Amaranthus spinosus* L. *Amaranthus hybridus* L.	Ndam et al., 2014; Chauhan and Jhonson, 2009	Amaranthaceae	6	South West region of Cameroon
3	*Voacanga Africana* (Benth)	Ndam et al.2014	Apocynaceae	2	South West region of Cameroon
4	*Ageratum conyzoides* *Synedrella nodiflora* (Gaertn) *Triplotaxis stellulifera* (Benth) *Vernonia amydalina* Del. *Emilia coccinea* (Sims) G. Don *Chromolaena ordorata* L. *Erigeron floribundus* (Kunth)	Ndam et al., 2014	Asteraceae	14	South West region of Cameroon
5	*Ceiba Pentandra* (L.) Gaernt	Ndam et al., 2014	Bombacaceae	2	South West region of Cameroon
6	*Carica papaya*	Ndam et al., 2014	Caricaceae	2	South West region of Cameroon
7	*Combretum hispidum* L	Ndam et al., 2014	Combretaceae	2	South West region of Cameroon
8	*Commelina diffusa* Bum F. *Commelina benghalensis* L.	Ndam et al., 2014; Bharati, 2016	Commelinaceae	4	South West region of Cameroon
9	*Ipomoea batata* (L.) Lam *Ipomoea involucrate* P. Beauv	Ndam et al., 2014	Convolvulaceae	4	South West region of Cameroon
10	*Momordica charantia* L.	Ndam et al., 2014	Cucurbitaceae	2	South West region of Cameroon
11	*Mariscus alternifolius* Vahl *Cyperus rotundus* L	Ndam et al., 2014; Bharati, 2016	Cyperaceae	4	South West region of Cameroon
12	*Dioscorea alata* L.	Ndam et al., 2014	Dioscoreaceae	2	South West region of Cameroon
13	*Phyllanthus amaurus* Shumach *Acalypha ciliate* Forsk *Manihot esculentus* Crant	Ndam et al., 2014	Euphorbiaceae	6	South West region of Cameroon
14	*Desmodium abdescendens* (Sw.) DC var. Abdescendens *Centrosema pubescens* Benth *Phaseolus vulgaris* L.	Ndam et al., 2014	Fabaceae	6	South West region of Cameroon
15	*Albizia zygia* (DC) J.F. Macbr.	Ndam et al., 2014	Mimosaceae	2	South West region of Cameroon
16	*Pteridium aquilinum* (L.) Kuhn subsp. Aquilinum	Ndam et al., 2014	Dennstaedtiaceae	2	South West region of Cameroon
17	*Ocimum graticcimum* L *Plectranthus aromaticus* Rox	Ndam et al., 2014	Lamiaceae	4	South West region of Cameroon
18	*Gloriosa superb* L	Ndam et al., 2014	Liliaceae	2	South West region of Cameroon
19	*Sida acuta* (L) Burm *Glyphaea brevis* L.	Ndam et al., 2014	Malvaceae	4	South West region of Cameroon
20	*Ficus exasperate* Vahl	Ndam et al., 2014	Moraceae	2	South West region of Cameroon
21	*Peperomia pellucid* (L.) Kunth	Ndam et al., 2014	Piperaceae	2	South West region of Cameroon
22	*Eleusine indica* (L) Gaertn *Oplismenus cf bumannii* Retz *Andropogon tectorum* Schum *Cynodon dactylon* L.	Ndam et al., 2014 Bharati 2016	Poaceae	8	South West region of Cameroon

Table 1. (Continued) Percentage contribution of plant families in the formation of weed flora in maize field in South West region of Cameroon and Pokhara, Nepal

23	*Paullinia pinnata* L	Ndam et al., 2014	Sapindaceae	2	South West region of Cameroon
24	*Talinum triangulare* Jacq	Ndam et al., 2014	Portulacaceae	2	South West region of Cameroon
25	*Solanium nigrum* L *Solanium torvum* Swartz	Ndam et al., 2014	Solanaceae	4	South West region of Cameroon
26	*Fleurga aestuans* Linn *Laportea alatipes* Hook F.	Ndam et al., 2014	Urticaceae	4	South West region of Cameroon
27	*Zingeber officinalis* Schum	Ndam et al., 2014	Zingiberaceae	2	South West region of Cameroon
28	*Achyranthes aspera* L. *Alternanthera sessilis* (L.) DC. *Amaranthus lividus* L.	Thapa, 2001 Thapa, 2001 Thapa, 2001	Amaranthaceae	-	Pokhara, Nepal
29	*Ageratum conyoides* L. *Ageratum houstonianum miller* *Artemisia indica willd*	Saini and Angiras, 1998 Thapa, 2001 Thapa, 2001	Asteraceae	-	Pokhara, Nepal
30	*Bothriosperum tenellum Fisch. Mey* *Brassicaceae* *Cardamine hirsuta L.* *Rorippa dubia (Pers.) Hara*	Thapa, 2001 Thapa, 2001 Thapa, 2001	Boraginaceae	-	Pokhara, Nepal
31	*Cyperus difformis L.* *Cyperus esculentus L.* *Cyperus niveus Retz.* *Cyperus rotundus L.* *Fimbristylis dichotoma (L.) Vahl* *Kyllinga brevitolia rottb.* *Mariscus sp.* *Scirpus sp.*	Thapa, 2001 Saini and Angiras 1998 Thapa, 2001 Thapa, 2001 Thapa, 2001 Thapa, 2001 Thapa, 2001 Thapa, 2001	Cyperaceae	-	Pokhara, Nepal

These weed species are responsible for reducing grain yield of maize as well as other crops through competing for nutrients, water, space and harbor insects and pathogens which badly affect plant growth and development. About 70% yield losses have been observed in maize due to weed infestation (Malviya and Singh, 2007). Likewise, Sharma et al. (2000) also found 33-50% yield loss by weeds in maize. Shad et al. (1993) found that first 3rd to 6th week after emergence of maize growth period are very sensitive to weed infestation due to narrower canopy which couldn't suppress excessive weed growth. Due to higher time consumption and higher labor cost for hand weeding, chemical methods have come in common practice as easier, economic and effective method of weed control at present context (Bundiniene et al., 2008). Mulching method is also used for managing weed population in maize field sustainably (Verdu et al., 2007). In this review, crop-weed competition, critical period of weed competition (CPWC), weed control methods, use of herbicide tolerant crops, yield loss by weeds and economics of weed control are thoroughly discussed.

1. Critical period of crop-weed competition

Diversification of weed species depends upon topography, soil type, temperature, season, cultivated crops, field management etc. (Fried et al., 2008; Necajava et al., 2015). Weeds are very tolerant to several biotic and abiotic factors. Higher adoption and competitive ability of weeds than cultivated crops are due to its higher seed production ability (Mertens and Jansen, 2002) and longer seed viability (Egley and Chandler, 1978).

The above-mentioned weeds are some of the dominant weeds observed in Pokhara, Nepal (Thapa, 2001). Though diversification of weed species occurs according to space and time, some of the weed population remained constant. They are *Digitaria spp, Amaranthus retroflexus* and *A. viridis* (Sharma and Nayital, 1993), *Echinochloa colonum* (Shad et al., 1993). Among total maize weeds, 90% of population were covered by grassy weeds like *E. colonum* and *E. crusgalli*, sedges like *Cyperus iria and C. esculentus* and broad-leaved weeds like *Commelina benghalensis* and *Ageratum conyzoide*s studied at Himachal Pradesh, India (Saini and Angiras, 1998).

Since, weeds compete with crop for nutrients, water and space etc. so critical period of weed control (CPWC) should be known accurately to prevent possible yield loss of any crop by weed infestation. In integrated pest management (IPM) approach, determination of CPWC plays vital role in weed control and management (Swanton and Weise, 1991). Detailed works are still required to properly understand the crop-weed competitive interrelationship, physio-chemo and biological link for developing better weed control and management methodologies which could be easy if CPWC is already determined (Weaver and Tan, 1987). The CPWC is the most sensitive period of crop to be easily affected by weed competition. Zimdahl (2004) found that first 3 to 6-week period of maize growth is most sensitive for weed control than later growth stages which can highly decrease final yield if proper management is neglected to be done.

Shad et al. (1993) found that 3 and 5 weeks after sowing is the most critical period of weed infestation in maize crops observed at Islamabad, Pakistan. Tyagi et al. (1993) found that weed population must be controlled in between 2-6 weeks after sowing (WAS) in maize crop to maximize yield as of weed free maize field. Ghosheh et al. (1996) observed that heavy infestation of *Sorghum halpense* weed in maize occurred within 3 to 6.5 weeks after sowing. Use of post-emergence herbicide Nicosulfuron @ 35g/ha found more effective than pre-emergence herbicides to control grass type weeds in maize field (Tapia et al. 1997). Porwal (2000) concluded that period between 4-6 WAS was very critical period for controlling weeds. Higher yield loss occurred due to weed infestation in same period. Kamble et al. (2005) also found 4-6 WAS as the most critical for weed infestation. Sohrab and Ali (2009) observed that about 5% of yield loss could be controlled if weed in maize filed are controlled in between CPWC of 5 to 15 days after emergence. From above research findings, CPWC concluded by different researchers ranged in between first 3rd to 8th week of growth stage. So, weeds must be controlled and managed properly for minimizing yield loss of maize crop.

Yield losses due to weeds

Weeds have been showing cosmopolitan character reducing yield and quality of crop plants. Due to lack of technical knowledge in farmers, they are still unable to reduce negative impact of weed infestation in crop yield. Crop yield loss have been observed by weeds, pathogens, insects, storage pests, rodents and other with the contribution of 33%, 26%, 20%, 17%, 6% and 8%, respectively in India (Kulshrestha and Parmar, 1992). Financially, weeds have caused monetary loss of 7.09 billion US$ as estimated by Ministry of Agriculture, India (Agarwal, 2007). Yaduraju (2012) found that weeds have caused 13 billion US$ losses per annum. Likewise, about 11 billion US$ loss have been created by weed infestation in crop yield (Gharde et al., 2018). Besides yield loss, the direct impacts of weed infestation on input use efficiency and grain quality have been observed as detrimental in food crops. Oerke and Dehne (2004) concluded that weeds have caused 37% crop yield loss globally. Whereas, Chikoye and Ekeleme (2003) have reported maize yield loss of 20 to 80% by weed infestation. Application of Atrazine @ 0.25 kg/ha as post emergence herbicide during knee high and tasseling stage produced highest grain yield (7.1 t/ha) in winter maize crop (Dixit and KC, 1993).

The application of Atrazine @ 1.0 kg/ha and followed by Glyphosate @ 1.0 kg/ha also showed good crop yield reducing weed infestation followed by the performance of above combination (Sreenivas and Satyanarayana, 1994). Whereas, application of mixture of Atrazine and metolachlor @ 1 and 1 kg/ha respectively as pre-emergence herbicide followed by one hand weeding at 5.5 WAS showed significantly high yield with high return value in maize crop (Subramanyam et al., 2001).

Economics of weed control

Due to lack of good coordination between agri-economists and weed researchers, economic analyses of weed management are still not done adequately (Wiles, 2004). If cost required to control and manage the weeds get equal with cost value of loss caused by weed infestation then it is considered as economic threshold point of weed management (Cousens, 1987). Coble and Mortensen (1992) concluded that estimation of threshold point can be determined by studying cost of applied

herbicides for weed control and cost required for prevention of loss by weeds.

The net return of US$ 84.18 (INRs. 5977) per hectare came as outcome of application of Atrazine @ 0.25 to 1 kg/ha as pre-emergence herbicide and further followed by manual weeding method applied at 40 DAS significantly higher than traditional method with return value of US$ 79.09 (INRs. 5616)/ha (Singh et al., 1991). Application of pre-emergence herbicide Atrazine @ 1.0 kg/ha and followed by post emergence herbicide 2,4-D Na salt @ 0.5 kg/ha showed maximum net return from crop. Higher economic return value of US$ 56.47 (INRs. 4010) to US$ 219.38 (INRs 15,576) / ha were observed as result of all weeding methods compared to non-weeding method in crop yield. Among all methods, maximum return value of Rs. US$ 219.38 (INR15576)/ha was observed in baby corn yield as the result of application of alachlor @ 1 kg/ha as pre-emergence herbicide which was followed by one hand weeding at 30 DAS (Pandey et al., 2002). Kolage et al. (2004) found that highest net income of US$ 179.80 (IN Rs. 12766)/ha with benefit-cost ratio of 2.50 was obtained as the result of application of Atrazine @ 1.0 kg/ha as pre-emergence herbicides. Patel et al., (2006) concluded that application of combination of Atrazine and pendimethalin which showed similar result of Atrazine and metolachlor combination created highest net income of US$ 222.97 (INRs. 15, 831)/ha with benefit cost ratio of 2.71. Likewise, Deshmukh et al. (2008) found that benefit-cost ratio and yield increased as result of application of Atrazine @ 0.75 kg/ha as pre-emergence herbicide followed by one hand weeding at 6.5 WAS in maize field.

3.Methods of weeds control

3.1.Preventive methods

Preventive control of weeds includes all actions taken to prevent the introduction and spread of unwanted plants. Although preventive measures will reduce invasion, no program can eliminate a wide range of weed species in a given field. The success of a preventive program varies according to the weed species, the amount and the persistence of the effort that it dedicates to prevention. Some preventive measures consist of use clean seed, use well decomposed FYM/Compost, removal of weed growth or keep irrigation and drainage channels clean or free from seeds, avoidance of use of sand or soil from weed infested area, avoidance of allowing cattle to move from weed infested areas to clean or cultivated areas, cleaning of all the farm implements and machinery properly after their use in infested areas and before using in clean areas and keeping farm fences, roads and bunds clean or free from weeds.

Rather than control methods, use of prevention methods is more effective and economical to save yield of any crop from weed infestation. Some safe measures like soil solarization (Candidoa et al., 2011), mulching (Ramakrishna, 2006), hot water and steam treatment (Smeda and Wetson, 1995; Hansson and Svensson, 2004), stale sed bed technique, laser treatment (Mathiassen et al., 2006), and robotic system (Perez-Ruiz et al., 2012) could be used as more effective methods for prevention of weed infestation in maize crop.

4.2 Manual weed control

Farmers have been using manual weeding as simple and old method of controlling weeds. In both cultivated and uncultivated lands, manual weeding is commonly practiced. Research done in Himachal Pradesh, India concluded that use of hoeing followed by two manual weeding in maize field increased yield by 0.36 t/ha (Singh et al., 1991). Sandhu and Bhatia (1991) found that effect of using Atrazine 5 times repeatedly as chemical method and two hand weeding method were responsible to give non-significant difference in maize yield. Research done at Rachi, India showed that hand weeding done at 3 and 5 days after sowing (WAS) reduced weed infestation significantly (Saha and Srivastava, 1992). Thakur (1994) found that significant control of weed infestation could be done if two hand weeding (3 and 5WAS) are practiced that gives similar yield produced by chemical treatment of Metolachor (1.25 kg/ha).

Weed control by chemical method after infestation showed significantly lower yield in maize compared to hand weeding done as preventive measure experimented in Greece (Eleftherohorinos et al., 1995). Intodia et al. (1996) found hand weeding as more effective method to reduce both the population density and dry matter of

weeds than chemical method because after 4 WAS, effectiveness of chemical decreased rapidly. In rainfed condition, manual weeding is more commonly practiced than other methods (Krishnamurthy and Krishnamurthy, 1996). High labor cost, time, and hard to operate in tough soil conditions are some disadvantages of using manual weeding. Kandasamy and Chandrasekhar (1998) found two times hand weeding to be efficient method to control weed population and thus increased maize yield up to 3.12 t/ha. Sharma et al. (2000) found that weeds can be reduced to maximum if hoeing followed by earthing up at 2 and 4 WAS, respectively, are practiced. About 91.9% efficiency of weed control was achieved by hand weeding method (Sinha et al., 2003). Kolage et al. (2004) found that hand weeding done at 3 and 5 WAS significantly reduced weed density.

4.3 Chemical weed control

Chemical method of weeding is very easy, flexible and cheaper than using costly labors for weeding purpose. Furthermore, this method is very useful in different climatic and edaphic conditions and shows effective results compared to tedious manual method of weeding. Both by increasing herbicide use efficiency and reducing injury to crop by applying recommended doses, an individual can improve his economy maximizing yield of crop reducing weed infestation easily by chemical method (Sutton et al., 2002).

For weed control and management of maize crop, Atrazine (2 – chloro – 4 – ethylamino – 6 - isopropylamino - 1,3,5 - triazine) and 4-hydroxyphenylpyruvate dioxygenase (HPPD) inhibiting herbicide which can also control Glyphosate resistant weeds like *Amaranthus palmeri* are generally used (Sutton et al., 2002; Swanton et al., 2007; Vyn et al., 2006). Walsh et al. (2012) concluded that Atrazine can be used as both pre and post emergence herbicide and can be applied solely or mixing with other herbicides too. The broad spectrum weed control ability can be applied in different plant growth stages, easily used by mixing with other herbicides, relatively safe to crop plants etc. have made HPPD- inhibiting herbicide commonly used in maize field (Walsh et al., 2012; Bollman et al., 2008; Stephenson and Bond, 2012).

The both pre and post emergence herbicides are necessary to be applied to get effective weed control in crop field. After the well growth and development of plant, post emergence herbicide can be used (Singh and Arya, 1994). For weed control, application of Atrazine @1 kg/ha followed by Glyphosate as pre and post emergence applied at 6 WAS increased maize yield by 98% (5.7 t/ha) whereas yield increased by 107% (6.0 t/ha) as two hand weeding done compared to non-weeded condition (2.9 t/ha). Likewise, *Cyperus rotundus* can be easily eliminated if Atrazine and Glyphosate herbicide are applied (Thakur and Singh, 1989). Gaur et al. (1991) found that only broad leaf weeds but not all narrow leaf weeds were controlled by the application of Atrazine @ 0.50 kg/ha and 2, 4-D @ 0.50 kg/ha as pre and post emergence herbicides. Sandhu and Bhatia (1991) concluded that significantly positive result could be obtain using Atrazine @ 0.75 kg/ha for controlling grasses as well as broad leaf weeds compared to hand hoeing method. High yield of maize was obtained as the result of application of Atrazine as both pre and post emergent herbicides applied at sensitive growth stages with a dose of 0.75 kg/ha and 0.25 kg/ha, respectively (Dixit and Gautam, 1993). The mixture of Atrazine and Pendimethalin mixed @ 0.5 kg/ha and 0.25 kg/ha, respectively applied as pre-emergence to control weeds showed elimination of 98% weed population (Patel et al., 2006). Bijandeh and Ghadiry (2006) also found that 85% weed control efficiency shown by applied mixture of Alachlor and Atrazine @ 1.92 and 1.5 kg/ha as pre-emergence in maize field. Whereas, S-metolachlor @ 0.87 kg/ha mixed with Atrazine @ 1.12 kg/ha applied as pre-emergence and mixture of nicosulfuron, rimsulfuron and Atrazine @ 0.013, 0.0 13 and 0.84 kg/ha as post emergence reduced 85% of total maize field weeds (Whaley et al., 2006). Walia et al. (2007) found that maize yield increased by 53.9% as Atrazine and Alachlor combination mixed @ 0.75 and 1.25 kg/ha was applied as pre-emergence in field. Whaley et al. (2009) found that weeds, morning glory and smooth pigweed population were decreased up to 94 and 99%, respectively when mixture of mesotrione and S-metolachlor @ 0.15 and 1.0 kg/ha was applied as pre-emergence herbicide. Some weeds could be controlled up to 99% by 30 days after application of mixture of post emergence herbicide like mesotrione and Atrazine @ 0.10 and 0.56 kg/ha, respectively due to mechanism of synergy effect (Woodyard et al., 2009).

4.4 Integrated weed Management

Different possible methods are used for controlling weeds as per needed sustainably belongs to integrated weed management (IWM) system (Swanton and Weise, 1991). IWM is being believed as sustainable form of weed control and management system that gives durable results conserving environment too (Swanton and Wiese 1991; Harker et al., 2012; Shaner 2014; Liebman et al., 2016). Sole use of any control method can't give satisfactory result. So, proper combination of different methods is required for sustainable control and management of weeds enhancing the crop yield (Swanton and Weise, 1991).

Application of Atrazine or Pendimethalin @ 1.0 kg/ha and doing hand weeding at 4WAS showed better reduction of weed population as compared to sole application of herbicides only (Paradkar and Sharma, 1993). Bhuvaneswari et al. (2002) and Reddy et al. (2002) also obtained similar kind of findings. Significant crop yield occurred as the result of application of Atrazine @ 0.5 kg/ha as pre-emergence and intercultural operation i. e. hand weeding done at 5 WAS than non-weeded method (Mundra et al., 2002) pre-emergence. Application of half of total recommended dose of Alachlor / Pendimethalin / Atrazine as pre-emergence herbicide followed by hand weeding operation @ 4 WAS showed significant enhancement of crop yield reducing weed infestation effectively compared to sole application of herbicide at its full recommended dose (Pandey et al., 2002). Efficient weed control with increased crop yield was observed after the application of Paraquat @ 0.5 kg/ha at 2 WAS and followed by hand weeding on 6 WAS, respectively (Reddy et al., 2002).

CONCLUSION

Weeds are omnipresent and substantially reduce yield and quality of crops. Worldwide yield losses in maize due to weeds are estimated around 37%. It is reported that weed infestation is one of the major causes that leads 20 to 80% reduction in maize yield. The variation in critical period of crop weed competition is reported which ranges in between two and six weeks after maize sowing but most critical is found in between 4-7 weeks after sowing. Weed control measures should be taken in this period to minimize losses, and water and nutrients use efficiency of maize can be enhanced. Different weeds control methods have their own advantages and disadvantages. Manual weeding requires large amount of labor makes it uneconomical especially where labor is expensive. Now a day's chemical weed control is gaining wider acceptability with the farmers in different situations. It would be wise to use different methods based on need. Most of the studies highlighted the importance of use of Atrazine (pre or post emergence) alone or combination with other herbicides plus manual methods for controlling weeds and obtaining higher returns. Some studies also reported its importance not only in weed control but in increasing the photosynthetic rate of maize plants. Therefore, it can conclude that none of the single weed control approach can provide complete solution. However, if various components of integrated weed management are implemented in a systematic manner, it can provide complete weed control with higher economic returns. Therefore, it is suggested to adopt IWM approach that can contribute to reduced use of herbicides and focus on sustainable crop production. Moreover, development of multi herbicides tolerant maize cultivars for effective control of all weeds is also necessary.

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