DIFFERENT WEED MANAGEMENT TECHNIQUES IN MAIZE (*ZEA MAYS L.*) – A REVIEW

Abstract

Farmers are subjected to yield loss due to different reasons including weed invasion. As weed management is a major approach different methods are incorporated for their management like cultural, mechanical and chemical etc. Different strategies are required for eradication as cultural methods can't be used in large area as application of herbicide or tillage methods are found effective in such conditions. Use of compatible herbicides is necessary as they have different way of approach to weeds as different weed species are observed on field. From this review it is concluded that cultural as well as chemical means both are effective when used in a significant manner and application is done according to land area taken into consideration.

Keywords – Maize, weed flora, Weed management and Yield loss

Introduction

Weeds pose a serious threat to agricultural output and contemporary agriculture must control them efficiently to avoid yield reduction and guarantee food security. Weed dynamics are impacted by intensive agriculture, a changing environment and natural disasters, which necessitates a shift in weed management procedures. Due to manpower constraints, manual control methods are no longer an option and chemical control methods are constrained by eco-degradation, health risks, and the emergence of herbicide tolerance in weeds. So, we are looking at several potential effective, viable, and non-traditional weed control methods for contemporary agriculture. Tillage regime improvement has long been recognised as a powerful weed-control strategy. It has been demonstrated that seed predation and harvesting weed seed control are potential methods for lowering weed appearance and seed reserve requirements. Due to development in the discipline of allelopathy for weed control new methods have came into existence and an extraordinary contribution has been made by biotechnological development in advancement to herbicide resistance in crop by utilising crop alleopathic potential and bio herbicides in contemporary to strategy of weed management. When conservation farming system strategy was observed particularly, thermal weed management was discovered and was considered as most effective weed control technique. Finally, precise weed control has been sufficiently described. If observed practically, the importance of remote sensing, modelling and robotics in pinpoint weed management has been emphasized (Bajwa *et al.* 2015).

Due to their high cost-effectiveness, usage of herbicides have been the chief method for domination of weed in developed nations for around 50 years. Resistance of weed to herbicides has been brought up by the widespread use of herbicides, and this issue is still becoming worse. The past ten years have seen significant worries about the future ability to control weeds in various crop systems due to the emergence of resistance to the once-dominant pesticide glyphosate. In addition, a variety of herbicide therapeutic effects have evolved resistance in various weed species. Weed management plans will inevitably require the employment of strategies other than herbicides as a booster due to the lack of modern herbicides with unique mechanisms of action (Micheal *et al.* 2016). But if we move to cultural patterns, The potential effects of cover cropping on a variety of demographic processes, such as weed juvenile growth from soil, plant survival, seed production, and seed predation, have led to its recommended inclusion as a crucial component of integrated weed management techniques (Liebman *et al.* 2021). For this, variable planting technique to be optimised without raising the producer's overall seed cost, a ratio between the portion of land planted at low density for weed management and the region to be planted at high density is required.. The relationship between productivity changes and planting density is typically nonlinear. In a prior study, it was found that for cotton, maize and soybean, doubling plant counts did not result in a reduction of each plant's productivity (Ethridge *et al.* 2022).

For many agricultural operators, controlling weed resistance has become a big concern. Weed resistance is increasing in both the quantity of resistant weeds and the number of herbicides to which they are developing resistance. We contend that resistance regulation must be considered as a sinful problem with no universal solution due to the rising number of weeds that susceptibility of weeds is not individual issue. It is necessary to adopt a common viewpoint that integrates a better comprehension of the human components of weed control in order to identify farmland administration strategies that assist farmers in strongly addressing resistance of weeds. We suggest that a human-centric approach to weed regulation is required through an understanding of wicked problem features. We provide guidelines for such methods using lessons discovered from resolving other wicked agricultural and resource conservation concerns. Herbicide resistance management options can be built through technical assistance, education, incentive programmes, legislative initiatives, and other strategies, but they will need to diverge from existing attempts to solve the riddle of additional potent weed management (Raymond *et al.* 2016).

An essential objective of weed research is to study the quantity and spread of species diversity within the territory of an agro-ecosystem. An indicator of a weed species geographic range is its distribution. In order to understand how a population evolves over time in relation to selective pressures imposed by our farming techniques, it is useful to investigate the quantity and distribution of weed populations. But, if we manage agricultural land for both productivity and biodiversity, accurate assessments of these two fundamental variables are crucial (Nkoa *et al.* 2015).

Weed flora in maize

Being undesirable and damaging weeds have some distinctive characteristics which make persistent in nature. Some researchers have studied them according to there species and also classified them. As Karde *et al.* (2020) reported that different species of maize associated weeds were *Cyperus rotundus L.* under sedges. Broad leaved weeds included *Euphorbia spp., Corchorus fascicularis L., Parthenium hysterophorun, Amaranthus viridis, Commelina benghalensis L., Acalypha indica L., Abutilon hirtum, Phyllanthus niruri, Boerhavia coccinea, Argemone Mexicana L., Achyranthus aspera L., Celosia argentea L., Cardiospermum helicacabum L., Euphorbia geniculata Orteg., Xanthium strumarium L.* supervened by grassy weeds like *Cynodon dactylon L., Eriochloa spp* and *Sorghum halepense L.* Singh *et al.* (2022) observed different weed community during dual experimental season were grassy weeds including *Echinochloa colona, Digitaria sanguinalis, Phalaris minor, Panicum maximum* and *Eleusine indica*, broad-leaved weeds including *Parthenium hysterophorus, Chenopodium album, Trianthema monogyna, Phyllanthus niruri* and *Mallugo stricta* and sedge including *Cyperus rotundus*. Rajesh *et al.* (2018) also stated that in well drained clay loam soil in Tamil Nadu he noted broadleaf weeds like *Trianthema portulacastrum, Boerhavia diffusa* and *Digera arvensis* also grass such as *Echinochloa colona, Dactyloctenium aegyptium* and *Eleusine indica*. *Cyperus rotundus* was under sedge. As observed by researchers and their data monitored it can be concluded that change in location of crop or sowing season some weeds are persistent and are observed many times.

Similarly, Pant *et al.* (2022) noted variety of weeds which include weeds like *Eleusine indica, Echinochloa colona* under grassy weeds. *Trianthema monogyna* and *Celosia argentea* was under broad leaved and sedge including *Cyperus iria*. Barla *et al.* (2016) also proclaimed that trial field was beset by weeds like *Digitaria sanguinalis, Echinochloa crusgalli, Echinochloa colona, Dactyloctenium aegyptium* and *Paspalam distichum*. *Cyperus iria, Fimbristylis milliaceae* and *Cyperus rotundus* under sedge and broad leaved weeds were *Phyllanthus niruri, Commelina benghalensis, Commelina nudifolia, Alternenthara sessils, Ageratum conyzoides*. In the experimental area *Cleome viscose L., Digera arvensis L., Commelina benghalensis L., Boerhavia erecta L., Euphorbia hirta L.* and *Celosia argentea L.* took place under broad leaf weeds as reported by Gharsiram *et al.* (2022) and in grasses *Digitaria sanguinalis (L.), Sorghum helepense (L.), Brachiaria reptans (L.)* and *Dactyloctenium aegyptium (L.)* was observed and sedge included *Cyperus rotundus L.* The control of weeds is aided by classifying them by species because each has a unique life cycle and range of influence.

Ghosh *et al.* (2021) reported different weed species in maize which includes *Setaria viridis (L.), Leptochloa chinensis (L.), Dinebra retroflexa, Cynodon dactylon (L.), Dactyloctenium aegyptium (L.)* among grasses. *Euphorbia hirta L., Trianthema portulacastrum L., Digera arvensis L., Euphorbia microphylla L., Amaranthus viridis L., Commelina benghalensis L.* under broad leaf weed and sedge comprised of *Cyperus esculentus L.* and *Cyperus rotundus L.* According to Swetha *et al.* (2015), weeds such as *Digitaria sanguinalis, Cynodon dactylon, Dactyloctenium aegyptium, Rottboellia exaltata* and *Echinochloa spp*. among grasses have taken over the experimental field. One type of sedge was *Cyperus rotundus*. *Commelina benghalensis, Amaranthus viridis, Trianthema* *portulacastrum, Parthenium hysterophorus, Digera arvensis* and *Euphorbia geniculata*. According to Nagasai *et al.* (2018), *Cyperus rotundus* dominated other weeds such as grasses like *Cynodon dactylon* and among broad leaf weeds *Phyllanthus niruri, Digera arvensis, Trianthema portulacastrum* and *Cleome viscosa*. *Cyperus rotundus* being most observed in field creates competition as they have rapid emergence and higher growth rate.

During experimental duration of two years, Kumar *et al.* (2017) reported presence of dominant weeds in Palampur, Himachal Pradesh in silt clay loam soil condition having infestation of weeds like *Polygonum alatum, Cyperus iria, Echinochloa colona, Ageratum conyzoides, Commelina benghalensis, Panicum dichotomiflorum* and *Digitaria sanguinalis*. Paul *et al.* (2020) also identified major weeds in experimental field of Madurai, Tamil Nadu and weeds identified under broad leaf weed were *Boerhavia erecta, Acalypha indica, Commelina benghalensis, Cleome viscosa, Eclipta alba, Croton sparsiflorus, Phyllanthus niruri, Phyllanthus maderaspatensis* and *Trianthema portulacastrum*. Grass species include *Dactyloctenium aegyptium, Echinochloa colonum*, while sedge had *Cyperus esculentus* and *Cyperus rotundus* included. In Bihar, *Cyperus rotundus L., Anagallis arvensis L., Nicotiana plumbeginifolia L., Chenopodium album L., Melilotus indica L., Fumaria parviflora L., Cannabis sativa L., Polypogon monspeliensis L.* and *cynodon dactylon L.* were among the top infesting weeds that Roy *et al*. (2008) discovered in weedy check. According to Singh *et al*. (2012), *Phyllanthus niruri, Cleome viscosa, Trianthema monogyna, Echinochloa colona, Digitaria sanguinalis,* and *Brachiaria ramose* were some of the weeds that uniformly infected the experimental field at the Norman E. Borlaug Crop Research Center, Pantnagar in 2009 and 2010.

When observed according to location some weeds are not repeated at several locality as they belong to specific climatic conditions and soil type as Stanzen *et al.* (2017) discovered top-tier weeds infesting maize fields in Jammu, including *Cynodon dactylon, Echinochloa crusgalli, Setaria glauca* in grassy and *Cyperus rotundus* under sedge. *Amaranthus viridis* and *Celosia argentea* were observed as broad leaf weeds. Tarundeep *et al.* (2016) stated weed flora in maize as *Arachne racemosa, Dactyloctenium aegyptium, Echinochloa colona, Amaranthus viridis, Digitaria sanguinalis, Trianthema portulacastrum, Commelina benghalensis, Eragrostis tenella, Euphorbia hirta, Cyperus rotundus, Phyllanthus niruri, Euphorbia microphylla, Digera arvensis* and *Cyperus compressus* in sandy loam soil conditions at PAU, Ludhiana. Accordingly Aditya *et al.* (2014) also had a study and recorded main weeds found in maize crops as sedge comprising *Cyperus rotundu*s, brad leaf weeds involving *Trianthema portulacastrum*, *Commelina benghalensis* and *Echinochloa colona* was among grassy weeds.

As maize is deep rooted and tall it's easier to differentiate between weed and crop, even as Kakade *et al.* (2016) observed an experimental field and recorded crucial weed infestation during *Kharif* season including weeds like *Dinebra arabica, Alternanathera triandra, Xanthium strumarium, Euphorbia hirta, Celosia argentea, Panicum spp, Tridax procumbens, Cynodon dactylon, Parthenium hysterophorus, Commelina benghalensis, Phyllanthus niruri, Digera arvensis, Cyperus rotundus, Amaranthis viridis* and *Euphorbia geniculata*. In addition, *Trianthema portulacastrum L., Melilotus alba L., Euphorbia geniculate L., Tridax* *procumbens L., Commelina spp., Amaranthus viridis L.* and *Parthenium hysterophorus L.* were observed as broad leaf weeds in maize by Madhavi *et al.* (2014). The only sedges included was *Cyperus rotundus L.* and grassy included *Digitaria spp., Dactyloctenium aegyptium L., Eleusine indica L., Cynodon dactylon L.,* and *Dinebra arabica L.*

Weeds being tenacious decreases worth of crop and there occupancy of area is needed to be observed as Sanodiya *et al.* (2013) noticed different weeds in field which were *Cyperus rotundus (16.2%), Echinochloa colona (15.4%), Commelina communis (14.0%), Eclipta alba (13.6%), Phyllanthus niruri (14.4%)* and *Digiteria sanguinalis (13.1%)* were present in the field. In contrast, *Cyperus rotundus L.* and other sedges were among the main weed flora that Arvadiya et al. (2012) noted in the experimental field. Among broad leaf weeds *Amaranthus viridis L., Digera arvensis L., Trianthema spp , Alternenthara sessili L.,* and *Portulaca oleracea L.* were noted. Among grassy weeds *Echinochloa crusgalli L.* and *Cynodon dactylon L.* were observed.

From all the data stated in above observations, 76 different weed species were observed in maize from which 26 were grassy weeds, 45 were broad leaf weeds and 5 were sedges.

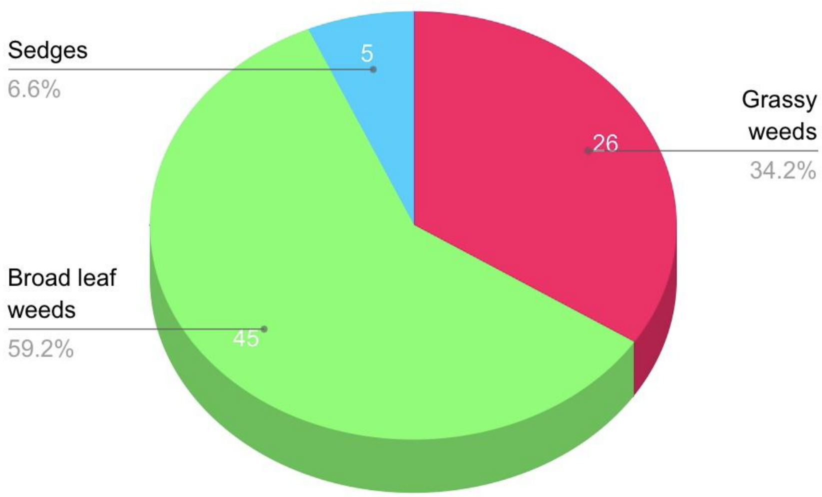

Fig 1 – Types of weeds observed

Table 1: Major weeds observed

Sr. No	Weed type	Weed species	Observed in reference	Total reference
1	Grassy weeds	*Cynodon dactylon*	9	20
		Digitaria sanguinalis	7	20
		Dactyloctenium aegyptium	8	20
		Echinochloa colona	9	20

2	Broad leaf weeds	*Amaranthus viridis*	7	20
		Commelina benghalensis	10	20
		Phyllanthus niruri	9	20
		Trianthema portulacastrum	8	20
		Digera arvensis	8	20
3	Sedges	*Cyperus rotundus*	17	20

Crop weed competition

Negative interaction between crop and weed leads to crop weed competition competing for discrete factors important for growth of both species. For managing yield losses field should be weed free as weeds are capable of suppressing main crop. According to Krishnaprabhu *et al.* (2020) if adequate management is disregarded during the crucial period of 15–45 day for crop weed competition, yields will be suffered. According to Babiker *et al.* (2013), the important periods for controlling weeds are 2–9 weeks in the summer and 2–8 weeks in the winter.

Yield loss in maize

There are different reasons for yield loss in different crops as climate including heat wave, cold wave etc and these conditions can't be controlled by humans. But conditions like moisture stress and weed density can be controlled. By neglecting these factors losses can be observed in field. Some researchers have studied effects of weed on maize crop yield and recorded data on the basis of trials conducted from which Ramachandran *et al.* (2012) mentioned that 40% loss in yield are seen due to substantial reduction in growth and development and under uncontrolled weed growth factor it can be greater than 70 %. Similarly, Anil *et al.* (2015) observed that endurance and growth in weed count reduces grain yield of maize by 27-60 % in *Rabi* maize and Dharam *et al.* (2018) observed that 77 to 97 % elevated grain yield is seen in maize than weedy check when proper weed management practices are taken under consideration. Das *et al.* (2016) observed that nature and intensity of weed infestation can cause losses in grain yield which can range from 28-100 % in *Kharif* maize due to substantial weed infestation. Likewise observations were recorded by Kumar *et al.* (2017) and noticed that maize yield loss can happen and can range from 28 to 100%, if weeds are not controlled in a timely manner during the crucial phase. Kakade *et al.* (2016) stated that competition of crop and weed can cause complete crop failure up to 33% . Uncontrolled weed growth in *Rabi* season was observed by Paramjeet *et al.* (2014) in sandy loam soil of Jammu and Kashmir and stated 62.25% reduction in seed yield. Some researchers classified impact of weed according to species and in that case Yakadri *et al.* (2015) observed the condition in sandy loam soil of Rajendranagar, Hyderabad, Telangana that 38, 44 and 77 % reduction in grain yield is seen by impact of sedges, non-grassy weeds and grasses.

Weed management practices

Cultural weed management

Cultural weed management techniques plays important role in weed management as weeds are completely discarded in some methods like HW, tillage practices and earthing up etc. Use of mulch is also observed as it suppress weed growth and mostly impacts on moisture and nutrient conservation model. Lakshmi *et al.*(2017) recorded higher weed control efficiency with lowest weed biomass and weed density with HW at 20 and 40 DAS. Similarly Bahar *et al.* (2020) significantly recorded lowest weed density and dry matter during knee height, tasseling stage and harvesting stage with earthing up and weeding at 30 and 45 DAS while studying effect of weed management practices on weeds. Changes in HW timing is necessary because climatic conditions are discrete in different regions as rainfall and temperature also affects weed growth. Different weed species have mismatched germination timing. Barad *et al.* (2016) noted lowest weed biomass with intercultivation and HW at 30 and 15 DAS and was at par with treatment of atrazine @ 0.5 kg/ha *fb* intercultivation and HW at 30 DAS. In an experiment to increase the productivity, profitability, and energy efficiency of hybrid maize by tillage and weed management techniques, Nayak *et al.* (2022) found that the highest stover and grain yield was recorded by applying HW at 20 and 40 DAS with yield attributes like rows per cob, seed index and seeds per row. According to Singh et al. (2015), intercropping of maize with cowpea and one HW with metribuzin spray @ 250 g/ha was at par with atrazine application with one HW as they recorded lower weed indices. Herbicide use in conjunction with any cultural practise has notable effects in field.

Chemical weed management

Farmers are always in search of economically satisfactory techniques as cultural management is mostly comprised of labour intensive which indirectly leads to investment of more money in field expenses and time consumption. If observed according to effectiveness culture techniques and chemical techniques are nearly at par, but cultural techniques cannot be used by farmers having large area.

Effect of different combinations of herbicides were studied by Bhagat *et al.* (2019) and noted highest stover and grain yield along with different parameters like grain weight and grains per cob with application of atrazine @ 0.75 kg/ha + tembotrione @ 100 g/ha at 15 to 20 DAS when compared with other herbicide combinations and dosage. Combinations of herbicides of different classes are used as every class of chemical affects specific weed type, may be grassy, broadleaf or sedge. Chhokar *et al.* (2019) studied combinations of mesotrione and atrazine for diverse weed flora management and noticed higher weed control efficiency with application of mesotrione + atrazine @ 91 + 909 g/ha in two year experimental period with significant grain yield. Similarly PE treatment of atrazine *fb* PoE tembotrione with atrazine @ 1000 g/ha and 120 g/ha + 500 g/ha noted maximum grain yield in contrast with other herbicide combinations, according to research by Mitra *et al.* (2018) who tested numerous herbicide combinations. According to Reddy *et al.* (2012), maximum grain yield was recorded by tank mix execution of glyphosate with atrazine @ 800 + 750 g/ha and was

170% elevated than the unweeded control. They also produced the least amount of weed density and dry biomass. Such combinations are rare as glyphosate is non selective herbicide but is most effective on weeds. A tank mix application was also executed by Walia *et al.* (2007) which recorded elevated grain yield with herbicides like pendimethalin and atrazine with dosage @ of 500 g and 750 g/ha in contrast with other herbicidal treatments. To suppress mixed weed flora, sequential utilization of PE and PoE herbicide was studied by Nazreen *et al.* (2017) and found that the application of alachlor *fb* halosulfuron-methyl + tembotrione (tank mix) (@1000 and 67.5 + 100 g/ha) 1 + 20 DAS resulted in the maximum grain production, as well as yield parameters such test weight and number of seeds per cob. As said by Sharma *et al.* (2018) after studying effects tank mix applications of tembotrione and atrazine, treatment of tembotrione + stefes mero + atrazine @ 120 g/ha + 733 g/ha +500 g/ha as applied after 17 DAS recorded higher weed control efficiency along with low density and dry weight. Triveni *et al.* (2017) found that in comparison to treatments without combinations, high herbicide efficiency index (%) and weed control efficiency (%) was noted by treating field with atrazine and tembotrione @ 500 + 50 g/ha with lowest weed index. Herbicide applications that are tank-mixed can increase the effectiveness of some compounds, lower application costs and provide a variety of treatments in a single application.

Dey *et al.* (2018) studied the morpho-physiological traits of sweet corn in relation to weed management and found that tembotrione @ 120g/ha and atrazine @ 1000 g/ha application significantly improved various growth attributes like crop dry matter, plant height, leaf area index and crop growth rate. Kakade *et al.* (2020) mooted least weed dry matter, density and weed index by the application of atrazine @ 500 g/ha *fb* tembotrione @ 120 g/ha at 20 DAS resulting in highest weed control efficiency during evaluation of PE and PoE herbicides in maize yielding significant results. As Wiqar *et al.* (2022) also noted good yield attributes like grains per row, their weight and grains per cob along with grain yield by execution of atrazine as PE @ 1500 g ai/ha *fb* tembotrione as PoE @ 120 g ai/ha when compared to other treatments. Here Wiqar *et al.*, Dey *et al.* and Kakade *et al.* have operated same herbicides with a different dosage of atrazine which changes potential of every treatment. In a comparative evaluation of the effectiveness of various herbicides to suppress different types of weed, Kumar *et al.* (2019) noted lowest weed dry weight and density by atrazine application @ 1500 g/ha as PE *fb* halosulfuron @ 90 g/ha at 25 DAS. In contrast with other treatments, a significant weed index and weed control efficiency was observed. As atrazine is specific for broadleaf and grass, maximum weeds are covered under it and that's why it is widely for different combinations.

Solo application of herbicide is also an effective measure taken against weed, if weeds of similar species are observed in field. When compared to various herbicidal treatments, Dharam *et al.* (2018) found that tembotrione when combined with surfactant @ 120 g/ha + 1000 ml/ha and applied as PoE recorded effective results against non grassy as well as grassy weeds. Likewise Kaur *et al.* (2016) studied complex weed flora management with PoE herbicides and noted that atrazine @ 750 g/ha recorded highest weed control efficiency (75.7 & 79.3 %) at 60 DAS in contrast to glyphosate and paraquat which are non- selective herbicides and Mukherjee *et al.* (2019) investigated several atrazine dosages over the course of a two-year experiment and found that atrazine @ 2 kg/ha as PE in the first cutting *fb* PoE in the second cutting had the highest weed control effectiveness, with a weed index of 0.2%. According to Paramjeet *et al.* (2014), spraying of atrazine as PE @ 500 g/ha notably decreased weed density and dry biomass measurements on sandy loam soils of Jammu. Similarly PE application of atrazine @ 1500 g/ha *fb* PoE spray of atrazine 750 g/ha by Kumar *et al.* (2012) resulted significantly increased weed control efficiency and preferably decreased weed dry weight. A study of integrated weed management was conducted by Kolekar *et al.* (2022) in maize and noted increased plant height, leaf area, dry matter and functional leaves by PE application of pendimethalin @ 1000 g ai/ha when compared to other treatments.

Integrated weed management

In order to manage weeds and reduce dependency on specific weed control methods, integrated weed management incorporates many agronomic strategies. According to research done by Behera *et al.* (2019) on the effects of brown manuring and various chemical combinations, atrazine + HW had prime outcome concerned to weed density and weed control efficiency. When Sesbania and crotolaria combined with pendimethalin sprayed at a rate of 1000 g/ha *fb* 2,4-D as PoE at 35 DAS, also demonstrated a considerable degree of weed control and were statistically comparable to atrazine and HW. As per a study, integrated weed management generally results in a higher level of weed control efficiency. According to Dutta *et al*. (2016), atrazine alone when applied as PE @ 2000 g/ha was comparable to PE application of atrazine 1000 g/ha *fb* HW at 30 DAS in terms of reduced dry weight and weed density of different types of weeds observed at different growth stages. Kaur *et al.* (2019) investigated the reduction of herbicide load in maize through the use of herbicides and paddy straw mulching and they found that tembotrione application at 110 g/ha noted maximum number of cobs, rows and grains per cob along with shelling and harvest index in Ludhiana, Punjab. Straw and other organic mulches are efficient at stopping the majority of weeds from germinating from seed. In the field study of Mandi *et al.* (2019) they found that atrazine @1000 g/ha + pendimethalin kg/ha + HW had recorded low weed dry biomass and density resulting in low weed index and high weed control efficiency in contrast with weedy check and other treatments.

Ramachandran *et al.* (2012) investigated the impact on yield, economics and weed growth in maize by conducting field experiment and found that combination of alachlor @ 1000 g a.i/ha as PE with brown manuring produced the highest grain and stover yield along with yield attributes like cob length, 100 grain weight and grains per cob as compared to other treatments.

Weed parameters influenced by weed management practices

As weed is an important factor considered and observed in field for there effective control and management different parameters are set to have a glance. Being dependent on each other these parameters have noteworthy assistance.

Weed density

Comprehension of weed population helps us to study effectiveness of treatment as according to Radheshyam *et al.* (2021), topramezone @ 25.2 g/ha or tembotrione application @120 g/ha as PoE herbicide at 15 DAS with 75% atrazine @750 g/ha as tank-mix or as a sequential application at 25 DAS after PE 75% atrazine significantly reduced the dry weight and density of weeds in *kharif* maize. Significant results were achieved by Hargilas *et al.* (2020) by applying atrazine @1500 g/ha as PE *fb* tembotrione @ 286 g/ha as PoE at 25 DAS and was in contrast to other herbicidal treatments, which resulted in significantly reduced weed density at 50 DAS. Following PE spraying of atrazine @ 1000 g/ha *fb* HW at 30 DAS, maximum weed control efficiency was observed by Sunitha *et al.* (2010) with least weed dry weight and density at harvest.

Employing weed management through cultural methods also have satisfactory impact as according to Mohanpuria *et al.* (2022), when plastic mulch and straw mulch were used in conjunction with surface and subsurface drip irrigation, the lowest weed density was observed. Results were superior to atrazine application through irrigation in furrows. In a study on the influence of integrated weed management practises with different parameters like growth, economics and yield of maize by Rani *et al*. (2013) they found that twice HW at 20 and 40 DAS recorded the lowest weed dry matter and weed density.

Tank mixtures and non-selective herbicide applications both produce notable results. Sonali *et al.* (2018) found that atrazine @ 1500 g/ha *fb* tembotrione @ 120 g/ha applied as a PoE treatment at 25 DAS resulted in least dry weight and weed density and was statistically comparable to pendimethalin @ 1000 ml/ha *fb* atrazine @ 750 g/ha + 2, 4-D amine and in accordance to Haji *et al.* (2012), atrazine application @ 1250 g/ha *fb* glyphosate application @ 2500 g/ha resulted with lowest weed dry weight and density in contrast to other treatments.

Weed biomass

Weed biomass alone is not sufficient to understand field weed condition as weight varies according to duration and species wise as effect of PE spraying of pendimethalin @ 1500 g/ha was observed by Sannagoudar *et al.* (2021), which produced much reduced weed dry weight than other weed management techniques, which in turn led to a higher grain yield and Oyeogbe *et al.* (2018) noted that herbicidal combination of atrazine + pendimethalin recorded less weed dry biomass when compared with brown manuring. According to Jain *et al.* (2022), the lowest mean weed biomass levels were found significantly at 30 DAS and 50 DAS as a result of stale seedbed + hoeing at 20 DAS + application of 5 t/ha of straw mulch at 30 DAS and stale seedbed + power weeder hoeing at 20 DAS + hoeing once at 40 DAS as observed.

As earthing up removes weeds from the root, Sultana *et al.* (2012) found lowest number of weed count and dry weight by executing two spading along with HW at 10 and 20 DAE + Earthing up at 30 DAE. Notable effect on grain yield of hybrid maize and weed biomass was observed in northern Bangladesh. Lowest weed biomass and density of weeds in maize was noted by Gaurav *et al.* (2018) by application of atrazine @ 1000 g/ha as PE *fb* 2, 4-D @ 500 g/ha at 30 DAS in contrast with PoE application of tembotrione at 100 or 125 g/ha.

Weed control efficiency

To understand condition of treatment at desired location over control plot is made easier by weed control efficiency as Sandeep et al. (2018) noted maximum weed control efficiency in maize by PE atrazine spraying @ 750 g/ha. When compared to alternative treatments, PoE spray of tembotrione @ 120 g/ha was found to be almost equivalent. As per Shingrup *et al.* (2014), PE spray of atrazine @ 750 g/ha *fb* PoE spray of 2,4-D have recorded maximum weed control efficiency. As per Arunkumar *et al.* (2019), the subsequent treatment of atrazine @ 500 g/ha as PE at 0-3 DAS *fb* tembotrione @ 125 g/ha as PoE at 30 DAS increased the effectiveness of weed control and grain production and was seen in contrast to the treatment of atrazine @ 500 g/ha PE at 0-3 DAS *fb* topramezone @ 75 g/ha PoE at 30 DAS. Also maximum weed control efficiency was noted by Wasnik *et al.* (2022) with spray of atrazine @ 1000 g/ha as PE at 2 DAS and conventional tillage with twice HW at 20 and 40 DAS. According to Hawaldar and Agasimani (2012), maximum weed control efficiency was successfully noted at all phases of crop growth by successional application of atrazine @ 750 g/ha *fb* 2,4-D @ 1000 g/ha.

Srividya *et al.* (2011) observed that tank mix atrazine application @ 1250 g/ha with paraquat @ 600 g/ha and application of *fb* pendimethalin @ 1500 g/ha with paraquat @ 600 g/ha recorded higher weed control efficiency and lowest weed index and was proportionate to intercropping with a power weeder and weed free check as weed index is used to observe percent reduction in yield under particular treatment.

Conclusion

Weeds being one of the most impacting factor on crop, needed to be prevented, eradicated and controlled prior to crop damage. So different weed controlling techniques are studied by researchers at distinct places to know effectiveness of specific treatment leading to higher weed control on field along with no damage to crop. In this article various weed management techniques are combined to enhance understanding of farmers as well as researchers also need innovative methods to study and apply. Dosage of different herbicides are studied deliberately specifically for famers betterment and their gains in field. As an agriculturist, economics should not be neglected, therefore tank mix application are also analysed above being most effective. Cultural as well as chemical treatments both being effective, farmers are sometimes restricted to use them due to certain conditions like no labour availability at specific time when needed etc. Integrated weed management are supreme in such conditions and can be executed on field giving desired results.

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