REVIEW ARTICLE Agricultural Reviews, Volume 41 Issue 4: 328-337 (December 2020)

Weed Management Practices in Maize (*Zea mays* L.): A Review

B. Sandhya Rani, V. Chandrika, G. Karuna Sagar, G. Prabhakara Reddy

10.18805/ag.R-1986

ABSTRACT

In India the highest loss (33%) is caused by weeds, followed by pathogens (26%), insects (20%), storage pests (7%), rodents (6%) and others (8%). Weeds compete with the crop for both above and below ground resources. Critical period of weed competition starts from 17 to 29 days after planting of corn, at an acceptable yield loss of 5 to 10 per cent. Herbicides are efficient tools for checking weed infestation and its usage is increasing throughout the globe due to increasing labour cost and quick weed control in various situations. The common weed management practice for Maize is pre-emergence application of selective herbicides like atrazine or pendimethalin followed by one hand weeding. Managing weeds through pre-emergence, post-emergence and sequential use of herbicides will be an ideal means for controlling the weeds in the view of economics and effectiveness in maize.

Key words: Economics, Enzyme activity, Maize, Microbes, Weed management, Yield.

Maize is known as “Queen of cereals” because of its high genetic yield potential and wider adaptability to different agro climatic zones. Initial slow growth and wider row spacing coupled with congenial environmental conditions allows luxuriant weed growth, with yield reduction from 28-100 per cent (Dass *et al.,* 2012). Weed infestation is supreme importance among the biotic factors that are responsible for low maize grain yield. Weed control practices in maize resulted in 77 to 96.7% higher grain yield than the weedy check. Hand weeding is most popular among the farmers but it is expensive, laborious and time-consuming. Herbicides usage for weed control is an important alternative to manual weeding because they are cheaper, faster and gives better weed control. Pre emergence herbicides especially atrazine is being used for control of weeds during the early stages but pre followed by early post emergence herbicide application is an ideal means for effective weed control during the entire crop growing season. Hence, a brief review is presented on the nature of weed spectrum in maize, competition between crops and weeds, their effect on growth and yield and different weed management practices for Maize.

Weed flora associated with maize

Rajesh *et al*. (2018) observed grasses like *Echinochloa colona, Eleusine indica and Dactyloctenium aegyptium, Cyperus rotundus*-the sedge and *Trianthema portulacastrum, Boerhavia diffusa* and *Digera arvensis* among the broad leaved weeds in maize in well drained clay loam soils of Madurai, Tamil Nadu. The experimental field of maize was dominated by grassy weeds (47.7 per cent) consisting of *Cynodon dactylon* (21.0 per cent), *Dactyloctenium aegyptium* (15.8 per cent) and major broad leaved weeds *Digera arvensis* (18.5 per cent), *Trianthema portulacastrum* (10.8 per cent) while *Cyperus rotundus* was the only sedge (10.2 per cent) (Ravi *et al*., 2017). The major weed flora associated with maize crop were *Amaranthus palmeri, Amaranthus rudis, Panicum fasciculatum, Urochloa texana, Echinochloa crusgalli, Brachiaria reptans* and *Acalypha ostryifolia* in Central and South-Central Texas, USA (Janak and James, 2016). The predominant weed flora reported in corn at Punjab Agricultural University, Ludhiana in sandy loam soils were *Arachne racemosa*, *Dactyloctenium aegyptium*, *Commelina benghalensis*, *Eragrostis tenella*, *Digitaria sanguinalis, Echinochloa colona, Trianthema portulacastrum*, *Phyllanthus niruri, Euphorbia hirta, Euphorbia microphylla, Digera arvensis, Amaranthus viridis, Cyperus rotundus and Cyperus compressus* (Tarundeep *et al.,* 2016). Kumar *et al.* (2015) reported that predominant weed species associated with maize in different locations of India were *Brachiaria ramosa*, *Digitaria sanguinalis, Dactyloctenium aegyptium, Eleusine indica, Cynodon dactylon, Digitaria setigera, Digitaria ciliaris, Leptochloa chinensis, Ageratum conyzoides, Galinsoga parviflora, Commelina benghalensis, Undernia cilata, Polygonum hydropiper, Euphorbia geniculata, Oxalis latifolia, Celosia argentea*, *Cleome viscosa, Sida acuta, Aschynomene indica, Acanthospermum hispidum, Portulaca oleracea, Phyllanthus niruri, Amaranthus viridis, Acalypha indica, Tridax procumbens, Ipomoea pestigridis, Parthenium hysterophorus, Euphorbia hirta, Cyperus rotundus* and *Cyperus iria.* Swetha *et al*. (2015) observed that the predominant weed species associated with corn were *Echinochloa* spp, *Digitaria sanguinalis, Dactyloctenium aegyptium* and *Rottboellia exaltata* among grasses and

Department of Agronomy, S.V. Agricultural College, Tirupati-517 502, Andhra Pradesh, India.

Corresponding Author: B. Sandhya Rani , Department of Agronomy, S.V. Agricultural College, Tirupati-517 502, Andhra Pradesh, India. Email: sandhya.reddy010@gmail.com

How to cite this article: Rani, B.S., Chandrika, V., Sagar, G.K. and Reddy, G.P. (2020). Weed Management Practices in Maize (*Zea mays* L.): A Review. Agricultural Reviews. 41(4): 328-337.

Submitted: 11-03-2020 **Accepted:** 03-10-2020 **Published:** 27-11-2020

broad leaved weeds were *Parthenium hysterophorus, Commelina benghalensis, Amaranthus viridis, Euphorbia geniculata, Digera arvensis* and *Trianthema portulacastrum* and only one sedge was *Cyperus rotundus* in sandy loam soils of Hyderabad. Aditya *et al.* (2014) reported that dominant weeds present in maize crop on sandy loam soils of IARI, New Delhi were *Echinochloa colona* among grassy weeds, *Cyperus rotundus* in sedges and *Commelina benghalensis* and *Trianthema portulacastrum* among the broad leaved weeds. Chand *et al.* (2014) observed that predominant weed species in maize in clay loam soils of RARS, CCS Haryana Agricultural University, Karnal were *Cyperus rotundus, Cynodon dactylon, Dactyloctenium aegyptium and Brachiaria reptans* among the grasses and *Phyllanthus niruri* and *Trianthema portulacastrum* among the broad leaved weeds.

Critical period of crop weed competition

Determination of the most critical period of crop weed competition for nutrients, moisture, light and space is of greater importance to make weed management practices more effective and economical and thereby increasing crop yields. Imoloame and Omolalye (2017) observed that weed interference in maize from 3-6 WAS significantly depressed the growth parameters and grain yield of maize. Kiranjit *et al.* (2016) noticed that in spring maize, the critical crop weed competition period starts from 30 DAS and ends at 60 DAS in sandy loams of Punjab Agricultural University, Ludhiana, India. Critical period for weed removal ranged from 21 to 29 days after planting of maize to prevent yield losses (Amare *et al.,* 2014). Fahad *et al.* (2014) reported that infestation of weeds at every stage of crop led to significant yield loss in maize. The period of high emergence of weeds in maize was between 3 and 8-10 weeks after planting (Takim *et al.,* 2014). Gantoli *et al.* (2013) observed that critical period for weed control starts from four to six leaf stage and continues until ten leaf stage or flowering of corn. The critical period of crop weed competition depends on the density, competitiveness and emergence periodicity of the weed population in maize (Bystro *et al*., 2012).

Yield loss due to weeds in maize

Weed control practices in maize resulted in 77 to 97 per cent higher grain yield than the weedy check (Dharam *et al.,* 2018). Grain losses in maize varied between 28-100 per cent, if weeds were not controlled during the critical period of crop weed competition (Kumar *et al.,* 2017b). During *Kharif* season maize suffers from heavy weed infestation, which may cause yield losses ranging from 28-100 per cent depending upon the intensity and nature of infestation of weeds (Das *et al.,* 2016). Imoloame and Omolalye (2016) observed 89 per cent yield loss in maize as a result of uncontrolled weed infestation. Weeds in maize cause substantial yield loss from 18 to 85 per cent (Jagadish *et al.,* 2016). Presence of weeds in winter maize reduced the maize yields by 27-60 per cent, depending upon the growth and persistence of weed population (Anil *et al.,* 2015). Hooda *et al.* (2015) observed that weeds in weedy check reduced the grain yield of maize by 57 to 56 per cent. Yakadri *et al.* (2015) stated that there was an yield reduction of 77, 44 and 38 per cent due to grasses, non-grassy weeds and sedges, respectively in maize on sandy loam soils of Rajendranagar, Hyderabad, Telangana. Paramjeet *et al.* (2014) observed that uncontrolled weed growth resulted in reduced seed yield by 62.25 per cent in maize on sandy loam soils of Jammu and Kashmir during *rabi* season. Singh *et al.* (2015) reported that weed infestation in rainfed maize caused yield loss varying from 28-70 per cent depending on intensity, nature and duration of weed competition.

Cultural control

Baldaniya *et al*. (2018) reported that in corn hand weeding twice at 20 and 40 DAS recorded the highest weed control efficiency of 76.5 per cent compared to pre and post emergence herbicide application treatments. Gupta *et al.* (2018) noticed that hand weeding at 20 and 40 DAS recorded the lowest density and dry weight of grasses, sedges and broad leaved weeds and improved the weed control efficiency at all the growth stages of maize crop compared to rest of the weed management practices tested. The highest green cob yield of maize was obtained with hand weeding twice at 20 and 40 DAS which was at par with pre emergence application of atrazine 1.0 kg ha^{-1} *fb* post emergence application of tembotrione 120 g ha^{-1} among the weed control treatments (Prithwiraj *et al.,* 2018). Satyendra *et al*. (2018) observed that hand weeding performed at 20 and 40 DAS remarkably reduced the density and dry weight of grasses, sedges and broad leaved weeds and improved the weed control efficiency at all the growth stages of maize crop. Chaitan *et al.* (2018) visualized that in maize two hand weedings at 20 and 40 DAS recorded significantly lowest weed density and dry weight at 30, 45 and 60 DAS. Hand weeding twice at 20 and 40 DAS recorded significantly higher plant height, leaf area index and dry matter production of sweet corn which was comparable with atrazine 1 kg ha^{-1} as pre emergence at 3 DAS + one hand weeding at 40 DAS (Kandasamy, 2017). The maximum grain yield of maize and minimum density and dry weight of all major weed species were recorded in two hand weedings at 15 and 30 DAS compared to rest of the treatments (Kumar *et al.,* 2017a). Tagoura and Ibrahim (2017) while working on maize found that two hand hoeings at 15 and 30 DAS exerted the highest decrease in total number and dry weight of weeds. Hand weeding twice at 20 and 40 DAS reduced the density and dry weight of grasses, broad leaved weeds and sedges at 30 and 60 DAS of corn and recorded the highest grain yield (Barla *et al.,* 2016). Dutta *et al*. (2016) reported that hand weeding twice at 20 and 40 DAS produced significantly higher values of number of cobs $plant^{-1}$, grain weight cob^{-1}, cob length and cob girth of corn compared to the other treatments. Stanzen *et al.* (2016) observed minimum density and biomass of weeds with two hand weedings at 15 and 30 DAS and recorded higher number of grains cob^{-1}, 1000 grain weight and grain yield of maize,

which was at par with pre emergence application of atrazine 1.0 kg ha^{-1}. Higher seed yield of maize was recorded with hand weeding twice at 20 DAS and 40 DAS due to reduced weed density and dry weight with higher weed control efficiency throughout the crop growing period (Dash and Mishra, 2014). Hand weeding and inter cultivation twice at 15 and 30 DAS recorded the lower weed population and dry weight at 30, 60 DAS and at harvest of maize, with lower weed index and higher weed control efficiency which was comparable to atrazine 0.5 kg ha^{-1} as pre emergence + HW at 30 DAS (Mathukia *et al.,* 2014). Birendra *et al.* (2013) recorded maximum plant height, grain weight cob^{-1}, 100 grain weight, cob length, cob diameter, number of grain rows cob^{-1}, number of grains cob^{-1} and higher grain yield of maize with lower weed population and dry weight with hand weeding twice at 15 and 30 DAS. Hand weeding at 15 and 30 DAS recorded significantly higher values of growth, yield attributes and yield of maize as compared to the rest of the weed control treatments (Kumar *et al.,* 2013). Lowest weed density, dry matter and highest WCE were recorded with hand weeding twice at 15 and 30 DAS in maize compared to pre emergence applications of pendimethalin or oxyfluorfen or atrazine (Madhavi *et al.,* 2013).

Effect of pre-emergence herbicide on weeds, crop growth, yield attributes and yield of maize

Gbaraneh and Briggs (2018) reported that pre emergence application of atrazine 2.5 l ha^{-1} + one weeding at 6 or 9 WAP produced significantly higher plant height, ear length, number of leaves $plant^{-1}$ and leaf area index at 10 weeks after planting in maize. Sahoo *et al.* (2017) found that the highest grain yield of maize was obtained with pre emergence application of atrazine 1 kg ha^{-1} at Main Agricultural Research Station, College of Agriculture, Dharwad. Shambulinga and Guggari (2017) reported that atrazine 1.0 kg ha^{-1} as pre emergence *fb* one hand weeding with inter cultivation at 45 DAS recorded the lowest total weed population, weed dry weight m^{-2}, higher weed control efficiency, higher cob length, cob girth, grain weight per cob, grain and straw yields of maize. Abdullahi *et al.* (2016) observed that pre emergence application of atrazine 1.0 kg ha^{-1} + one hand weeding at 45 DAS recorded significantly lowest weed density and weed dry weight and higher plant height, number of cobs $plant^{-1}$, cob length and girth, grain yield and harvest index of maize over other doses of atrazine along with hand weeding. Among the different herbicides tried, pre emergence application of atrazine alone 2.0 kg ha^{-1} or PE atrazine 1.0 kg ha^{-1} + HW at 30 DAS showed their superiority by reducing the density and dry weight of grasses, sedges and broad leaved weeds at all the stages of corn growth (Dutta *et al*., 2016). Pre emergence application of atrazine 0.75 kg ha^{-1} *fb* PoE application of 2,4-D 0.5 kg ha^{-1} was equally effective to that of pre emergence application of atrazine 0.75 kg ha^{-1} in increasing the plant height and dry matter production of maize at harvest (Javid *et al.,* 2016). Rasool and Khan (2016) found that PE application of atrazine 1.0 kg ha^{-1} + HW at 20 DAS recorded higher plant height, number of functional leaves, leaf area index, dry matter production and grain yield of maize. Nidhi *et al.* (2015) noticed that atrazine 0.75 kg ha^{-1} + glyphosate 2.5 ml $litre^{-1}$ of water (as PE tank mixture spray) or atrazine 1.5 kg ha^{-1} as PE + one hand weeding at 40 DAS was equally effective in increasing the number of kernel rows cob^{-1}, number of kernels ear^{-1}, weight of grains ear^{-1} and 1000 grain weight of maize. Pre emergence application of atrazine 1.0 kg ha^{-1} *fb* one HW at 30 DAS of corn produced lower weed density and dry weight with higher weed control efficiency, which was found superior over the rest of the herbicidal treatments tried (Samant *et al.,* 2015). Shankar *et al.* (2015) observed significantly lower density and dry weight of weeds in maize with atrazine 1.25 kg ha^{-1} as pre emergence when compared to other chemical weed management treatments. Deshmukh *et al.* (2014) reported that atrazine 1.0 kg ha^{-1} as PE *fb* mechanical or HW at 30 DAS proved better in reducing weed density, dry matter accumulation and with higher weed control efficiency in maize. Pre emergence application of atrazine 0.5 kg ha^{-1} at Jammu on sandy loam soils recorded significantly lower weed density and weed dry weight in winter maize (Paramjeet *et al.,* 2014). Kannan and Chinnagounder (2014) reported that the lower weed density was achieved with pre emergence application of atrazine at 0.5 kg ha^{-1} *fb* HW at 20 DAS in maize. Nadiger *et al.* (2013) observed higher grain yield of maize with pre emergence application of atrazine 1.25 kg ha^{-1} due to effective control of weeds with minimum density and dry weight of weeds. Pre emergence application of atrazine 1.0 kg ha^{-1} *fb* one hand weeding at 30 DAS recorded higher grain and stover yields of maize which was at par with HW at 20 and 40 DAS (Sanodiya *et al.,* 2013). Pre emergence application of atrazine 1.0 kg ha^{-1} + HW at 40 DAS was at par with HW at 20 DAS and inter cultivation at 40 DAS in increasing plant height, dry matter accumulation and days to 50% silking in maize compared to rest of the weed management treatments (Arvadiya *et al*., 2012). Suresh *et al.* (2012) reported that pre emergence application of atrazine 1.5 kg ha^{-1} *fb* post emergence application of atrazine 0.75 kg ha^{-1} recorded significantly lower weed dry weight and higher weed control efficiency compared to rest of the treatments in maize. In zero till maize, pre emergence application of atrazine 1.5 kg ha^{-1} was effective in controlling first flush of weeds than paraquat 1.5 l ha^{-1} or no herbicide treatment (Mukundam *et al*., 2011).

Effect of post emergence herbicides on weeds

Patel *et al.* (2019) observed that pre emergence application of atrazine 500 g ha^{-1} + pendimethalin 250 g ha^{-1} *fb* 2, 4- D 1000 g ha^{-1} as PoE provided effective control of monocot, dicot and total weeds and resulted in highest weed control efficiency in maize. Post emergence application of tembotrione 120 g ha^{-1} along with surfactant (1000 ml ha^{-1}) at 2- 4 leaf stage of weeds was found to be the most effective against grassy and non grassy weeds as compared to other

herbicidal treatments either applied as pre or post emergence application in corn (Dharam *et al.,* 2018). Sequential application of atrazine 1.0 kg ha^{-1} (PE) *fb* 2, 4- D 0.5 kg ha^{-1} at 30 DAS recorded the lowest weed density and dry biomass of weeds in corn when compared to PoE application of tembotrione 100 or 125 g ha^{-1} (Gaurav *et al.,* 2018). Mitra *et al*. (2018) revealed that in maize application of atrazine 1.0 kg ha^{-1} (PE) *fb* tembotrione + atrazine (120 g ha^{-1} + 0.5 kg ha^{-1}) as post emergence had resulted in significantly lower weed density and biomass, with highest weed control efficiency at 40 and 60 DAS. Post emergence application of tembotrione 125 and 150 g ha^{-1} with surfactant at 20 DAS significantly reduced the density and dry weight of weeds in maize which was followed by tembotrione 125 or 150 g ha^{-1} at 30 DAS (Rana *et al.,* 2018). Sandeep *et al.* (2018) concluded that in maize application of atrazine 750 g ha^{-1} as pre emergence or tembotrione 120 g ha^{-1} as post emergence proved to be equally effective in recording the lowest density and dry weight of weeds with highest weed control efficiency compared to other herbicides tried. Sonali *et al.* (2018) observed the lowest weed count and dry weight per unit area with pre emergence application of atrazine 1.5 kg ha^{-1} *fb* tembotrione 120 g ha^{-1} as PoE at 25 DAS which was statistically at par with pre emergence application of pendimetalin 1000 ml ha^{-1} *fb* atrazine 750 g ha^{-1} + 2, 4-D amine 0.4 kg ha^{-1} at 25 DAS as PoE in maize. Among the different herbicides applied as post emergence in maize, tembotrione 120 g ha^{-1} recorded significantly the lowest density and dry weight of grasses, broad leaved weeds and sedges with highest weed control efficiency (Sunil *et al.,* 2018). Post emergence application of topramezone 20.1 or 25.2 g ha^{-1} at 18 DAS of maize significantly reduced the weed density and dry weight than lower dose of 13.4 g ha^{-1} which indicates that lower dose of topramezone was less effective against weeds in comparison to its higher dose (Tiwari *et al.,* 2018). Hulihalli *et al.* (2017) noticed that application of atrazine 750 g ha^{-1} + 2, 4 -D amine (75%) at 25 DAS resulted in effective control of grasses, sedges and broad leaved weeds with higher weed control efficiency and lower weed index at 50 DAS and at harvest of maize, which was on par with atrazine 1.5 kg ha^{-1} as pre emergence *fb* tembotrione 120 g ha^{-1} at 25 DAS. Among the different herbicides tested the lowest weed density and biomass, higher weed control efficiency was recorded with application of atrazine 1.0 kg ha^{-1} (PE) *fb* PoE application of halosulfuron methyl 90 g ha^{-1} in maize which was comparable with hand weeding twice at 20 and 40 DAS (Lakshmi and Martin, 2017). Pre emergence application of atrazine 500 g ha^{-1} *fb* post emergence application of topramezone 70 g ha^{-1} recorded significantly lower weed density and dry weight in maize (Parul *et al.,* 2017). Lower weed density, dry matter, weed index and higher weed control efficiency was observed with pre emergence application of pendimethalin 1.0 kg ha^{-1} *fb* 2, 4-D amine 0.5 kg ha^{-1} at 20 DAS which was comparable with hand weeding twice at 15 and 30 DAS in maize (Devi and Venkateswarlu, 2017). Application of tembotrione 125 and 150 g ha^{-1} + surfactant at 20 DAS in corn recorded higher weed control efficiency and lowest weed index over the other treatments (Rana *et al.,* 2017). Sandeep *et al.* (2017) observed that sole application of halosulfuron methyl 135 g ha^{-1} at 30 DAS in maize significantly controlled *Cyperus rotundus* (95.2% mortality) as against that of weed free (98.8% mortality) treatment. Pre emergence application of atrazine at 750 g ha^{-1} and post emergence application of tembotrione at 120 g ha^{-1} were equally effective in reducing the density and dry weight of weeds in maize at harvest when compared to other weed management practices (Rawal *et al.,* 2017). Pre emergence application of atrazine 50% WP 1.0 kg ha^{-1} *fb* one hand weeding with intercultivation at 40 DAS of maize recorded lower total weed population and dry weight with higher weed control efficiency which was followed by post emergence application of topramezone 33.6 g ha^{-1} + MSO adjuvant at 20 DAS of maize (Shambulinga and Guggari, 2017). Sivamurugan *et al.* (2017) found that application of atrazine 1.5 kg ha^{-1} as pre emergence *fb* tembotrione 120 g ha^{-1} as PoE at 25 DAS recorded significantly lesser grassy weed count and weed dry weight at harvest of maize and it was comparable with the application of pendimethalin 1kg ha^{-1} as pre emergence *fb* atrazine 0.75 kg ha^{-1} + 2,4-D amine 0.4 kg ha^{-1} at 25 DAS as PoE. The lowest weed persistence index and highest weed control efficiency in sweet corn was recorded with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 25.2 g ha^{-1} at 25 DAS which was at par with atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 105 g ha^{-1} at 25 DAS (Swapna *et al.,* 2017). Post emergence application of topramezone 20.1 or 25.2 g ha^{-1} at 18 DAS of maize, with or without adjuvant was equally effective in reducing the weed density, dry weight and resulted in higher weed control efficiency than the lower dose of 13.4 g ha^{-1} or pre emergence application of atrazine alone 1.0 kg ha^{-1} (Tiwari *et al.,* 2017). Tikendra *et al.* (2017) noticed that sequential application of atrazine 1.5 kg ha^{-1} as PE *fb* 2, 4-D 0.4 kg ha^{-1} as PoE at 25 DAS of maize recorded the lowest weed density and dry weight at 60 DAS compared to pre emergence herbicide application alone or in combinations. The lowest weed density, dry weight and weed index was recorded with hand weeding at 20 and 40 DAS which was statistically at par with pendimethalin 1.0 kg ha^{-1} (PE) *fb* topramezone 25 g ha^{-1} at 20 DAS in maize (Rao *et al*., 2016).

Effect of post emergence herbicides on crop growth, yield attributes and yield of maize

Application of atrazine 500 g ha^{-1} + pendimethalin 250 g ha^{-1} as PE *fb* 2, 4-D 1000 g ha^{-1} as PoE recorded higher grain and stalk yield of maize and it was followed by application of topramezone 25.2 + atrazine 500 g ha^{-1} as PoE *fb* IC + HW at 30 DAS (Patel *et al.,* 2019). Ajay *et al*. (2018) reported higher plant height and dry matter accumulation at harvest in maize with the application of alachlor 2.0 kg ha^{-1} *fb* tembotrione 120 g ha^{-1} + surfactant at 35 DAS. Pre emergence application of atrazine 1.0 kg ha^{-1} *fb* 2, 4-D 0.5

kg ha^{-1} at 30 DAS recorded significantly higher grain and straw yields of maize and were statistically at par with atrazine 1.0 kg ha^{-1} *fb* one hand weeding at 30 DAS (Gaurav *et al*., 2018). Pre emergence application of atrazine 1.0 kg ha^{-1} at 3 DAS *fb* post emergence application of 2,4-D 0.75 kg ha^{-1} at 21 DAS recorded higher cob length, cob diameter, number of grains cob^{-1} and grain yield of maize (Kandasamy, 2018). Among the different weed management practices, atrazine as pre emergence 1.0 kg ha^{-1} *fb* tembotrione 120 g ha^{-1} + atrazine 500 g ha^{-1} as post emergence application recorded significantly higher grain yield of maize which was followed by atrazine 1.0 kg ha^{-1} pre emergence *fb* tembotrione as post emergence 120 g ha^{-1} (Mitra *et al*., 2018). Nazreen *et al.* (2018) reported that pre emergence application of alachlor 1000 g ha^{-1} *fb* post emergence application of halosulfuron methyl 67.5 g ha^{-1} + tembotrione 100 g ha^{-1} recorded higher plant height, leaf area index and dry matter production in maize at 20 and 40 DAS. Rana *et al.* (2018) noticed that post emergence application of tembotrione 125 and 150 g ha^{-1} + surfactant (20 DAS) resulted in higher number of kernel rows cob^{-1}, number of grains row^{-1}, number of grains cob^{-1} and grain yield of maize. Application of atrazine 750 g ha^{-1} as pre emergence or tembotrione 120 g ha^{-1} as post emergence proved to be statistically at par in increasing the growth parameters like plant height, leaf area index and dry matter accumulation by maize under irrigated conditions (Sandeep *et al.,* 2018). Post emergence application of tembotrione 120 g ha^{-1} recorded significantly higher plant height, dry matter production and grain yield which was at par with PoE application of tembotrione 110 g ha^{-1} (Sunil *et al.,* 2018). Tiwari *et al.* (2018) observed that post emergence application of topramezone 20.1 or 25.2 g ha^{-1} at 18 DAS resulted in the highest grain and straw yields of maize than the lower and higher doses of 13.4 and 33.6 g ha^{-1} respectively. Post emergence application of tembotrione 130 g ha^{-1} + surfactant 1000 ml ha^{-1} at 14 or at 21 DAS recorded the highest stature of plant height and more number of leaves $plant^{-1}$ in maize during *kharif* season (Ankush *et al.,* 2017a). Pre emergence application of atrazine 1.0 kg ha^{-1} on 3 DAS *fb* post emergence application of 2,4-D 0.75 kg ha^{-1} on 21 DAS excelled other treatments by recording higher values of plant height, leaf area index and dry matter production in maize (Kandasamy, 2017). Pradeep *et al.* (2017) reported that application of atrazine 1 kg ha^{-1} *fb* 2, 4- D sodium salt 1.0 kg ha^{-1} at 30 DAS recorded higher plant height, leaf area index and dry matter production by maize at 30, 60 and 90 DAS. Pre emergence application of atrazine 500 g ha^{-1} *fb* post emergence application of topramezone 70 g ha^{-1} recorded significantly higher plant height, leaf area index and dry matter production by maize (Parul *et al.,* 2017). Rana *et al.* (2017) noticed that post emergence application of tembotrione at 125 or 150 g ha^{-1} + surfactant at 20 DAS and tembotrione 150 g ha^{-1} without surfactant at 30 DAS gave higher crop resistance index and efficiency index of maize. Among the weed control treatments, weed free treatment resulted in significantly higher growth indices *viz.,* absolute growth rate (AGR), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) at 21- 40 DAS of maize but was at par with pre emergence application of atrazine 750 g ha^{-1} *fb* post emergence application of tembotrione 120 g ha^{-1} (Rawal *et al.,* 2017).

Effect of Herbicides on Enzyme Activity and Total Microbial Biomass in Soil

Bahirgul and Ramesh (2019) noticed that after 7 and 15 DAS of maize, significantly higher dehydrogenase activity was observed with the application of tank-mixtures of topramezone 12.5 g ha^{-1} + atrazine 625 g ha^{-1} and topramezone 12.5 g ha^{-1} + 2,4-D Na salt 500 g ha^{-1} (3.92 and 3.80 µg TPF g^{-1} soil day^{-1}, respectively) which was on par with weed free treatment (4.25 µg TPF g^{-1} soil day^{-1}). The lowest dehydrogenase activity was recorded in pre emergence application of atrazine 1.25 kg ha^{-1}. Significantly higher dehydrogenase activity was observed in weed free and weedy check in maize, followed by tank-mixtures of topramezone 12.5 g ha^{-1} + 2,4-D 500 g ha^{-1} and tembotrione 50 g ha^{-1} + 2,4-D 500 g ha^{-1} at 7 and 14 days after herbicide application, while the lowest was with atrazine 1 kg ha^{-1} (Varshitha *et al.,* 2019). Post emergence application of tembotrione 105 g ha^{-1} at 15 DAS increased the urease activity from 0 days after treatment (11.45) to 45 days after treatment (14.15) and there after decreased till harvest, whereas on the other hand, application of topramezone + atrazine 25.2 + 250 g ha^{-1} increased urease activity from 0 to 15 DAT and later decreased till harvest of maize (Aruna *et al.,* 2018). Tyagi *et al.* (2018) reported that beyond 40 days after application of atrazine 2.0 kg ha^{-1} and at harvest of maize, the population of fungi, bacteria and actinomycetes increased considerably justifying that there was no long term adverse effect of herbicides on the beneficial soil micro fauna and flora. Application of tembotrione at higher concentration of 130 g ha^{-1} showed a decreased activity of dehydrogenase activity in soil than the lower doses of tembotrione 110 g ha^{-1} and 120 g ha^{-1} from 20 to 60 DAS of corn. There was an increase in the enzyme activity from the 60^{th} to the 100^{th} day in all the treatments (Ankush *et al*., 2017b). The bacterial population was found to be higher under hand weeding twice at 15 and 30 DAS and weedy check treatments compared to pre emergence application of atrazine 1.5 kg ha^{-1} at 30 DAS of maize. All the herbicide applied treatments resulted in lower microbial population at 5 DAS and initial set back in microbial population was recorded over a period of 30 DAS (Silambarasan *et al.,* 2017). Pre emergence application of atrazine 1.5 kg ha^{-1}, mechanical weeding twice at 20 and 40 DAS and atrazine 1.0 kg ha^{-1} *fb* 2,4-D 0.5 kg ha^{-1} were comparable with one another in recording higher population of azotobacter in soil at harvest of maize (Rajinder *et al.,* 2015). Soil microbial population (bacteria, fungi and actinomycetes) at harvest of maize was not affected by application of pre emergence herbicides namely atrazine 0.25 kg ha^{-1}, metsulfuron methyl 0.003 kg ha^{-1}, metolachlor

1.0 kg ha^{-1} and anilofos 0.4 kg ha^{-1} sprayed at 3 DAS (Ramesh and Nadanassababady, 2015). Kamaiah *et al.* (2014) observed higher dehydrogenase activity in soil at 30 DAS of corn and at harvest with pre emergence application of atrazine 0.625 kg ha^{-1} + pendimethalin 0.5 kg ha^{-1} *fb* 2,4-D 0.5 kg ha^{-1}. Pre emergence application of atrazine 1000 g ha^{-1} or post emergence application of topramezone 16.8 g ha^{-1} + atrazine 250 g ha^{-1} with and without adjuvant and topramezone 25.2 g ha^{-1} + atrazine 250 g ha^{-1} with adjuvant recorded significantly lowest soil microbial biomass as compared to other treatments, whereas significantly higher soil microbial biomass was recorded in weedy check at 25DAS in maize (Veeresh *et al.,* 2014).

Economics

Bahirgul and Ramesh (2019) noticed that PoE application of topramezone 12.5 g ha^{-1} + atrazine 625 g ha^{-1} or topramezone 12.5 g ha^{-1} + 2,4-D 500 g ha^{-1} resulted in higher net returns and B:C ratio in maize. Patel *et al.* (2019) noticed that pre emergence application of atrazine 500 g ha^{-1} + pendimethalin 250 g ha^{-1} *fb* 2, 4-D 1000 g ha^{-1} as PoE recorded higher net returns and B:C ratio in maize and it was closely followed by application of topramezone 25.2 g ha^{-1} + atrazine 500 g ha^{-1} as PoE *fb* IC + HW at 30 DAS. Post emergence tank mix application of topramezone 12.5 g ha^{-1} + atrazine 625 g ha^{-1} at 20 DAS resulted in higher net returns in maize (Aruna *et al.,* 2018). Dharam *et al.* (2018) reported that post emergence application of tembotrione 120 g ha^{-1} along with surfactant (1000 ml ha^{-1}) at 2-4 leaf stage of maize resulted in higher B:C ratio as compared to other herbicidal treatments either applied as pre or post emergence. Pre emergence application of atrazine 1.0 kg ha^{-1} *fb* tembotrione + atrazine (120 g ha^{-1} + 0.5 kg ha^{-1}) as post emergence recorded highest net returns and B:C ratio when compared to other combinations of pre and post emergence herbicides (Mitra *et al.,* 2018). The highest net returns and B:C ratio in maize was recorded with pre emergence application of atrazine 1000 g ha^{-1} *fb* post emergence application of tembotrione 120 g ha^{-1} which was followed by hand weeding twice at 20 and 40 DAS (Prithwiraj *et al*., 2018). Pre emergence application of atrazine 750 g ha^{-1} + pendimethalin 750 g ha^{-1}, one day after sowing registered higher B:C ratio in maize, which was closely followed by atrazine 750 g ha^{-1} + 2,4-D amine salt 400 g ha^{-1} at 25 DAS as post emergence (Satyendra *et al.,* 2018). Sequential application of atrazine 1.5 kg ha^{-1} as pre emergence *fb* tembotrione 120 g ha^{-1} as post emergence recorded higher net returns and B:C ratio of maize in maize-wheat cropping system (Sonali *et al.,* 2018). Ankush *et al.* (2017b) realized highest marginal benefit cost ratio in maize with the application of tembotrione 130 g ha^{-1} + surfactant at 21 DAS than the lower doses of tembotrione 110 g ha^{-1} and 120 g ha^{-1} applied with and without surfactant. Among the different pre *fb* post emergence herbicide treatments in maize, maximum net returns and B:C ratio was recorded with atrazine 1.5 kg ha^{-1} as pre emergence *fb* halosulfuron methyl 60 g ha^{-1} as post emergence which was found to be at par with pendimethalin (1000 ml ha^{-1}) as pre emergence *fb* atrazine (750 g ha^{-1}) + 2, 4- Di methyl amine (500 g ha^{-1}) at 25 DAS as post emergence (Dharmendra *et al.,* 2017). Pre emergence application of atrazine 1.0 kg ha^{-1} *fb* topramezone 30 g ha^{-1} at 2-3 leaf stage of weeds resulted in higher gross returns, net returns and B:C ratio of maize in rice-maize system (Parameswari *et al.*, 2017). Rana *et al.* (2017) realized highest benefit cost ratio with the application of tembotrione 100 g ha^{-1} at 30 DAS which was closely followed by tembotrione 125 g ha^{-1} + surfactant at 20 DAS or tembotrione 100 g ha^{-1} at 20 DAS of maize. Sivamurugan *et al.* (2017) noticed that application of pendimethalin 1.0 kg ha^{-1} as pre emergence *fb* atrazine 0.75 kg ha^{-1} + 2, 4-Dimethyl amine 0.4 kg ha^{-1} at 25 DAS recorded higher net returns and B:C ratio in maize and it was followed by application of atrazine 1.5 kg ha^{-1} as pre emergence *fb* tembotrione 120 g ha^{-1} as PoE at 25 DAS. The highest B:C ratio in sweet corn was recorded with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 25.2 g ha^{-1} at 25 DAS which was closely followed by atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 105 g ha^{-1} at 25 DAS (Swapna *et al.,* 2017). Among the different pre and post emergence herbicides tested in corn, net monetary returns and B:C ratio was significantly higher with PoE application of tembotrione 50 g ha^{-1} + atrazine 0.5 kg ha^{-1} (Triveni *et al.,* 2017). Barad *et al.* (2016) realized higher net returns and B:C ratio in maize with pre emergence application of atrazine 0.5 kg ha^{-1} + HW and IC at 30 DAS compared to other treatments tried. Highest returns per rupee investment was recorded with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone spray 25 g ha^{-1} at 20 DAS which was followed by pendimethalin 1.0 kg ha^{-1} as PE *fb* topramezone spray 25 g ha^{-1} at 20 DAS compared to hand weeding twice in maize (Rao *et al.,* 2016). Among the different pre emergence herbicides applied in combination with HW and IC at 15 and 30 DAS, higher net returns and benefit cost ratio was registered with pre emergence application of atrazine 0.5 kg ha^{-1} + HW and IC at 30 DAS of maize (Dobariya *et al.,* 2015). Kamble *et al.* (2015) concluded that, most economical and effective method of weed control in maize was the pre emergence application of atrazine 1.0 kg ha^{-1} + one hoeing + one weeding at 20 DAS with the higher cost benefit ratio. Swetha *et al.* (2015) reported higher benefit cost ratio in maize with tank mix of topramezone + atrazine (25.2 + 250 g ha^{-1}) + MSO as PoE which was followed by atrazine 1000 g ha^{-1} as PE followed by intercultivation at 30 DAS.

REFERENCES

Abdullahi, S., Gautam, G. and Dawson, J. (2016). Effect of different weed control methods on growth and yield of maize (*Zea mays* L.) under rainfed condition in Allahabad. Journal of Agriculture and Veterinary Science. 9(4): 44-47.

Aditya, K., Singh, P.C. M., Jat, S.L., Bahadur, S. and Savita, S. (2014). Weed management strategies in maize (*Zea mays*): Effect on weed dynamics, productivity and economics of the maize- wheat (*Triticum aestivum*) cropping system in indo-gangetic plains. Indian Journal of Agricultural

Sciences. 85(1): 87-92.

Ajay, S., Chand, M. and Punia, S.S. (2018). Evaluation of different herbicides against complex weed flora in *kharif* maize. International Journal of Pure and Applied Biosciences. 6(5): 803-807.

Amare, T., Amin, M. and Negeri, M. (2014). Management of weeds in maize (*Zea mays* L.) through various pre and post emergence herbicides. Advances in Crop Science and Technology. 2(5): 1-5.

Anil, K., Jai, K., Puniya, R., Amit, M., Neetu, S. and Lobzang, S. (2015). Weed management in maize-based cropping system. Indian Journal of Weed Science. 47(3): 254-266.

Ankush, K., Rana, M.C. and Sharma, N. (2017a). Growth and yield of maize as influenced by different doses of tembotrione under mid-hill conditions of Himachal Pradesh. Proceedings of Biennial Conference of the Indian Science on Doubling Farmers Income by 2022: The Role of Weed Science, MPUAT, Udaipur, India, 1-3 March. 187.

Ankush, K., Rana, M.C., Neelam, S and Rana. S.S. (2017b). Effect of post emergence herbicide-tembotrione on yield, soil dehydrogenase activity and its phytotoxicity on maize (*Zea mays* L.) under mid hill conditions of Himachal Pradesh, India. International Journal of Current Microbiology and Applied Sciences. 6(8): 2297-2303.

Aruna, K.J., Rao, P.C., Madhavi, M. and Padmaja, G. (2018). Effect of herbicides on the activity of soil enzyme urease in maize crop. Indian Journal of Agricultural Research. 52(3): 300-304.

Arvadiya, L.K., Raj, V.C., Patel, T.U. and Arvadiya, M.K. (2012). Influence of plant population and weed management on weed flora and productivity of sweet corn (*Zea mays* L.). Indian Journal of Agronomy. 57(2): 162-167.

Bahirgul, S. and Ramesh, B. (2019). Influence of early post emergence herbicide mixtures on weed control and grain yield of maize (*Zea mays* L.) Acta Scientific Agriculture. 3(5): 26-28.

Baldaniya, M.J., Patel, T.U., Zinzala, M.J., Gujjar, P.B. and Sahoo, S. (2018). Weed management in fodder maize (*Zea mays* L.) with newer herbicides. International Journal of Chemical Studies. 6(5): 2732-2734.

Barad, B., Mathukia, R.K., Gohil, B.S. and Chhodavadia, S.K. (2016). Integrated weed management in *rabi* popcorn (*Zea mays* var. everta). Journal of Crop and Weed. 12(1): 150-153.

Barla, S., Upasani, R.R., Puran, A.N. and Thakur, R. (2016). Weed management in maize. Indian Journal of Weed Science. 48(1): 67-69.

Birendra, K., Ranvir, K., Suman, K. and Mizzanul, H. (2013). Integrated weed management studies on weed flora and yield in *kharif* maize. Trends in Biosciences. 6(2): 161-164.

Bystro, J.P., Leon, N.D. and Tracy, W.F. (2012). Analysis of traits related to weed competitiveness in sweet corn (*Zea mays* L.). Sustainability. 4: 543-560.

Chaitan, S., Aditya, K.C., Sathish, G. and Chandra, P.B. (2018). Weed dynamics and yield of *rabi* maize (*Zea mays* L.) as influenced by weed management practices. Journal of Experimental Biology and Agricultural Sciences. 6(1): 150-158.

Chand, M., Samar, S., Dharam, B., Narender, S. and Vijay, K. (2014). Halosulfuron Methyl: A new post emergence herbicide in India for effective control of *Cyperus rotundus* in Sugarcane and its residual effects on the succeeding crops. Sugar Technology. 1: 1-14.

Das, A., Kumar, M., Ramkrushna, G., Patel, D.P., Layek, J., Panwar, A.S. and Nagachan, S.V. (2016). Weed management in maize under rainfed organic farming system. Indian Journal of Weed Science. 48(2): 168-172.

Dash, R.R. and Mishra, M.M. (2014). Bioefficiency of halosulfuron-methyl against sedges in bottle gourd. Indian Journal of Weed Science. 46(3): 267-269.

Dass, S., Kumar, A., Jat, S.L., Parihar, C.M., Singh, A.K and Jat, M.L. (2012). Maize holds potential for diversification and livelihood security. Indian Journal of Agronomy. 57(3). 32-37.

Deshmukh, J.P., Shingrup, P.V., Dandge, M.S., Bhale, V.M and Paslawar, A.N. (2014). Integrated weed management in maize. Proceedings of "Biennial Conference of Indian Society of Weed Science on Emerging Challenges in Weed Management". Directorate of Weed Science Research, Jabalpur, Madhya Pradesh, India. February 15-17, 2014. 33.

Devi, B.R. and Venkateswarlu, B. (2017). Weed dynamics and yield of baby corn as influenced by nitrogen levels and weed control practices. Research Journal of Agricultural Sciences. 8(6): 1440-1445.

Dharam, B.Y., Ashok, Y., Punia, S.S. and Anil, D. (2018). Tembotrione for post emergence control of complex weed flora in maize. Indian Journal of Weed Science. 50(2): 133-136.

Dharmendra, K.K., Vikram, B., Abhinandan, S., Mritunjay, K. and Prasad, S.S. (2017). Impact of herbicides on yield, economics and phytotoxicity in *kharif* maize. The Pharma Innovation Journal. 6(11): 190-192.

Dobariya, V.K., Mathukia, R.K., Gohil, B.S. and Shivram, A. (2015). Integrated weed management in *rabi* sweet corn (*Zea mays var.Saccharata*). Journal of Eco-friendly Agriculture. 10(1): 70-83.

Dutta, D., Thentu, T.L. and Duttamudi, D. (2016). Effect of weed management practices on weed flora, soil micro flora and yield of baby corn (*Zea mays L.*). Indian Journal of Agronomy. 61: 210-216.

Fahad, S., Hussain, S., Saud, S., Hassan, S., Muhammad, H., Shan, D., Chen, C., Xiong, D., Cui, K. and Huang, J. (2014). Consequences of narrow crop row spacing and delayed *Echinochloa colona and Trianthema portulacastrum* emergence for weed growth and crop yield loss in maize. Weed Research. 54(5): 475-483.

Gantoli, G., Victor, R.A. and Ronald, G. (2013). Determination of the critical period for weed control in corn. Weed Technology. 27(1): 63-71.

Gaurav, S.K., Verma, R.S., Meena, A.C., Maurya, K and Sushil, K. (2018). Nutrients uptake and available nutrients status in soil as influenced by sowing methods and herbicides in kharif maize (*Zea mays* L.). International Journal of Agriculture, Environment and Biotechnology. 11(1): 17-24.

Gbaraneh, L.D and Briggs, S.A. (2018). Influence of timing and frequency of hoe weeding and herbicide application on maize yield in Port Harcourt, Nigeria. International Journal of Agriculture and Earth Science. 4(5): 1-12.

Gupta, S.K., Mishra, G.C and Purushottam, K. (2018). Efficacy of pre and post emergence herbicides on weed control in

kharif maize (*Zea mays* L.) International Journal of Chemical Studies. 6(1): 1126-1129.

Hooda, V.S., Yadav. H. and Kumar, A. (2015). Effect of planting and weed control methods on system productivity in maize-wheat cropping system. 25th Asian-Pacific Weed Science Society Conference on Weed Science for Sustainable Agriculture, Environment and Biodiversity. Hyderabad. India, 13-16 October 2015. 349.

Hulihalli, U.K., Shantveerayya, S. and Kabadag, C.B. (2017). Effect of herbicides on weed density and productivity of maize. The Bioscan. 12(1): 585-589.

Imoloame, E.O. and Omolalye, J.O. (2016). Impact of different periods of weed interference on the growth and yield of maize (*Zea mays* L.). Tropical Agriculture. 93(4): 245-257.

Imoloame, E.O. and Omolalye, J.O. (2017). Weed infestation, growth and yield of maize (*Zea mays* L.) as influenced by periods of weed interference. Advances in Crop Science and Technology. 5(2): 1-7.

Jagadish, K., Shrinivas, C.S., Prashant, C. (2016). A review on weed management on maize (*Zea mays* L.). Advances in Life Sciences. 5 (9): 3448-3455.

Janak, W.T. and James, G.W. (2016). Weed Control in Corn (*Zea mays* L.) as influenced by pre emergence herbicides. International Journal of Agronomy. 19(2): 1-9.

Javid, E., Desai, L.J., Ahir, N.B. and Joshi, J.R. (2016). Effect of integrated weed management on growth, yield, yield attributes and weed parameters on summer maize (*Zea mays* L.) under South Gujarat condition. International Journal of Science, Environment and Technology. 5(4): 2050-2056.

Kamaiah, I., Aravinda, K.B.N., Geeta, G.S. and Ramesh, B. (2014). Effect of tank mixture herbicides on phytotoxicity, soil dehydrogenase activity and nutrient uptake by weeds in maize (*Zea mays* L.). Trends in Biosciences. 7(14): 1839-1842.

Kamble, A.S., Yogeesh, L.N., Prashanth, S.M., Channabasavanna, A.S. and Channagoudar, R.F. (2015). Effect of weed management practices on weed growth and yield of maize. International Journal of Science, Environment and Technology. 4(6): 1540-1545.

Kandasamy, S. (2017). Effect of weed management practices on weed control index, yield and yield components of sweet corn. Journal of Agricultural Research. 2(4): 2-6.

Kandasamy, S. (2018). Studies on weed management in irrigated maize. Journal of Agricultural Research. 3(1): 1-3.

Kannan, S and Chinnagounder, C. (2014). Evaluation of bio-efficacy, weed control efficiency in herbicide resistant transgenic stacked and conventional corn hybrids (NK603xTC 1507) for crop productivity. International Journal of Scientific and Research Publications. 3(7): 22-29.

Kiranjit, S., Tarundeep, K., Bhullar,V. and Brar, A.S. (2016). The critical period for weed control in spring maize in north-west India. 61(1): 1-7.

Kumar, A., Kumar, J., Puniya, R., Mahajan, A. and Lobzang, S. (2015). Weed management in maize-based cropping system. Indian Journal of Weed Science. 47(3): 254-266.

Kumar, A., Rana, M.C., Sharma, N. Rana, S.S. (2017b). Effect of post-emergence herbicide-tembotrione on yield, soil dehydrogenase activity and its phytotoxicity on maize (*Zea mays* L.) under mid hill conditions of Himachal Pradesh. International Journal of Current Microbiology and Applied Sciences. 6: 2297-2303.

Kumar, B., Kumar, R., Kalyani, S. and Haque, M. (2013). Integrated weed management studies on weed flora and yield in *kharif* maize. Trends in Biosciences. 6(2): 161-164.

Kumar, B., Prasad, S., Mandal, D. and Kumar, R. (2017a). Influence of integrated weed management practices on weed dynamics, productivity and nutrient uptake of *rabi* maize (*Zea mays* L.). International Journal of Current Microbiology and Applied Sciences. 6(4): 1431-1440.

Lakshmi, P. and Martin, L.M. (2017). Pre and post emergence herbicides for weed control in maize. Indian Journal of Weed Science. 49(4): 403-404.

Madhavi, M., Ramprakash, T., Srinivas, A., Yakadri, M. (2013). Integrated weed management in maize (*Zea mays* L.) for supporting food security in Andhra Pradesh, India. The Role of Weed Science in Supporting Food Security by 2020. Proceedings of the 24th Asian-Pacific Weed Science Society Conference, Bandung, Indonesia, October, 22-25. 19.

Mathukia, R.K., Dobariya, V.K., Gohil, B.S. and Chhodavadia, S.K. (2014). Integrated weed management in *rabi* sweet corn *(Zea mays L. var. Saccharata*). Advances in Crop Science and Technology. 2(4): 2-4.

Mitra, B., Bhattacharya, P.M., Ghosh, A., Patra, K., Chowdhary, A.K. and Gathala, M.K. (2018). Herbicide options for effective weed management in zero-till maize. Indian Journal of Weed Science. 50(2): 137-141.

Mukundam, B., Srividya, S. and Raja, V. (2011). Productivity and economics of rice-zero till maize as influenced by weed management practices in Southern Telangana region of Andhra Pradesh. Indian Journal of Weed Science. 43 (3 and 4): 163-168.

Nadiger, S., Babu, R. and Aravinda, B.N.K. (2013). Bioefficacy of pre emergence herbicides on weed management in maize. Karnataka Journal of Agricultural Sciences. 26(1): 17-19.

Nazreen, S., Subramanyam, D., Sunitha, N. and Umamahesh, V. (2018). Growth and yield of maize as influenced by sequential application of herbicides. International Journal of Current Microbiology and Applied Sciences. 7(5): 2764-2770.

Nidhi, S., Komal, B.B., Lal, P.A., Bahadur, K.T. and Narayan, A. (2015). Weed dynamics and productivity of spring maize under different tillage and weed management methods. Azarian Journal of Agriculture. 2(5). 118-122.

Parameswari, Y.S., Srinivas, A and Ram Prakash, T. (2017). Productivity and economics of Rice (*Oryza sativa*)- zero till maize (*Zea mays*) as affected by rice establishment methods and weed management practices. International Journal of Current Microbiology and Applied Sciences. 6(10). 945-952.

Paramjeet, K., Anil, K., Sharma, B.C., Ranjeet, K and Neetu, S. (2014). Nutrient uptake as influenced by weed management in winter maize + potato intercropping system. Indian Journal of Weed Science. 46 (4): 336-341.

Parul, K., Tiwari, A.R., Sharma and Bhambri, M.C. (2017). Biennieal Conference of the Indian Science on “Doubling Farmers Income by 2022: The role of weed Science”, MPUA&T, Udaipur, India, 1-3 March, 2017. 227.

Patel, B.D., Chaudhari, D.D., Patel, V.J., Patel, H.K. and Mishra.A. (2019). Effect of herbicides applied to *kharif* maize on soil physio-chemical properties, microbial population and their residual effect on succeeding wheat crop. International Journal of Chemical Studies. 7(2): 705-708.

Pradeep, R., Sreenivas, G. and Leela, R.P. (2017). Impact of sustainable weed management practices on growth, phenology and yield of *rabi* grain maize (*Zea mays* L.) International Journal of Current Microbiology and Applied Sciences. 6(7): 701-710.

Prithwiraj, D., Pratap, T., Singh, V.P., Rohitashav, S. and Singh, S.P. (2018). Weed management options in spring sweet corn [*Zea mays* (L.) *saccharata*]. International Journal of Chemical Studies. 6(5): 647-650.

Rajesh, A.K., Venkataraman, N.S. and Ramadass, S. (2018). Integrated weed management in maize based intercropping systems. Indian Journal of Weed Science. 50(1): 79-81.

Rajinder, K., Dinesh, B., Neelam, S., Rana, S.S. and Pawan, P. (2015). Microbial properties of soil as influenced by weed control in maize pea cropping system under mid hill conditions of Himachal Pradesh. Himachal Journal of Agricultural Research. 42(1): 1-5.

Ramesh, G. and Nadanassababady, T. (2015). Impact of herbicides on weeds and soil ecosystem of rainfed maize *(Zea mays* L.). Indian Journal of Agricultural Research. 39(1): 31-36.

Rana, S.S., Badiyala, D., Neelam, S., Rajinder, K. and Pawan, P. (2017). Impact of tembotrione on weed growth, yield and economics of maize (*Zea mays* L.) under mid hill conditions of Himachal Pradesh. Pesticide Research Journal. 29(1): 27-34.

Rana, S.S., Dinesh, B., Neelam, S., Suresh, K. (2018). Evaluation of tembotrione against weeds in maize (*Zea mays* L.) under mid hill conditions of Himachal Pradesh. International Journal of Innovative Research in Technology. 5(3): 220-226

Sahoo, T.R., Hulihalli, U.K., Paikaray, R.K., Mohapatra, U. and Sethi, D. (2017). Saflufenacil: A new group of chemical herbicide for effective weed management in maize. International Journal of Chemical Studies. 5(1): 339-342.

Rao, C.H.R., Prasad, P.V.N. and Venkateswarlu, B. (2016). Assesment of different herbicides on yield and economics of *kharif* maize (*Zea mays* L.). International Journal of Agricultural Science and Research. 6(6): 409-414.

Rasool, S. and Khan, M.H. (2016). Growth and yield of maize (*Zea mays* L.) as influenced by integrated weed management under temperate conditions of North Western Himalayas. American Journal of Experimental Agriculture. 14(1): 1-9.

Ravi, D.S., Chinnusamy, C. and Nithya, C. (2017). Weed management in herbicide tolerant transgenic maize -A Review. Chemical Science Review and Letters. 6(24): 2364-2372.

Rawal, S., Dhindwal, A.S., Punia, S.S, and Ashok, Y. (2017). Physiological growth indices of quality protein maize (*Zea mays* L.) as influenced by different moisture regimes and weed control under semi-arid conditions. Annals of Agricultural Research. 38(3): 289-297.

Sahoo, T.R., Hulihalli, U.K., Paikaray, R.K., Mohapatra, U. and Sethi, D. (2017). Saflufenacil: A new group of chemical herbicide for effective weed management in maize. International Journal of Chemical Studies. 5(1): 339-342.

Samant, T.K., Dhir, B.C. and Mohanty, B. (2015). Weed growth, yield components, productivity, economics and nutrient uptake of maize (*Zea mays* L.) as influenced by various herbicide applications under rainfed condition. Scholar Journal of Agriculture and Veterinary Sciences. 2: 79-83.

Sandeep, P., Adyant, K., Mritunjay, K., Anup, K. and Hansraj, H. (2017). Efficacy of herbicides and their combination in *Cyperus* dominated *rabi* maize (*Zea mays* L.). The Bio Scan. 12(1): 533-537.

Sandeep, R., Dhindwal, A.S. and Punia, S.S. (2018). Response of furrow irrigated raised bed planted maize (*Zea mays*) to different moisture regimes and herbicides treatments under semi-arid conditions. Indian Journal of Agricultural Sciences. 88(3): 354-360.

Sanodiya, P., Jha, A.K. and Shrivastava, A. (2013). Effect of integrated weed management on seed yield of fodder maize. Indian Journal of Weed Science. 45(3): 214-216.

Satyendra, K.G., Mishra, G.C. and Purushottam. K. (2018). Efficacy of pre and post emergence herbicide on weed control in kharif maize (*Zea mays* L.). International Journal of Chemical Studies. 6(1): 1126-1129.

Shambulinga, K.M and Guggari, A.K. (2017). Effect of post emergence herbicides on weed growth and yield of irrigated maize. Journal of Farm Science. 30(3): 421-423.

Shankar, K.A., Yogeesh, L.N., Prashanth, S.M., Channabasavanna, A.S. and Channagoudar, R.F. (2015). Effect of weed management practices on weed growth and yield of maize. International Journal of Science, Environment and Technology. 4(6): 1540-1545.

Silambarasan, M., Sathyamoorthy, N.K., Dhananivetha, M., Vikram, S.K. and Kathiravan, V. (2017). Effect of drip herbigation on native microbial population in maize. Journal of Pharmacognosy and Phytochemistry. 6(5): 2696-2698.

Singh, A.K., Parihar, C.M., Jat, S.L., Singh, B. and Sharma, S. (2015). Weed management strategies in maize (*Zea mays)*: Effect on weed dynamics, productivity and economics of the maize-wheat (*Triticum aestivum)* cropping system in Indo-gangetic plains. Indian Journal of Agricultural Sciences. 85(1): 87-92.

Sivamurugan, A.P., Ravikesavan, R., Yuvaraja, A., Singh, A.K. and Jat, S.L. (2017). Weed management in maize with new herbicides. Chemical Science Review and Letters. 6(22): 1054-1058.

Sonali, B., Debnath, S., Abhijit, S. and Benukar, B. (2018). Weed management in maize system in new alluvial zone of West Bengal, India. International Journal of Current Microbiology and Applied Sciences. 7(4): 1344-1350.

Stanzen, L., Kumar, A., Sharma, B.C., Puniya, R. and Sharma, A. (2016). Weed dynamics and productivity under different tillage and weed management practices in maize (*Zea mays*) - wheat (*Triticum aestivum*) cropping sequence. Indian Journal of Agronomy. 61(44): 449-454.

Sunil, K.V., Peeyush, K.J., Maurya, A.C., Sushil,K., Deepak, K.Y. and Vijay, P. (2018). Bio-efficacy of tembotrione 34.4% SC on diverse weed flora and productivity of *kharif* maize (*Zea mays* L.). International Journal of Agriculture, Environment and Biotechnology. 771-775.

Suresh. K., Rana, S.S., Chander, N. and Angiras, N. (2012). Management of hardy weeds in maize under mid-hill conditions of

Himachal Pradesh. Indian Journal of Weed Science. 44(1): 11-17.

Swapna, N., Padmaja, B. and Revathi, P. (2017). Effect of sequential application of herbicides on weed persistence index and on nutrient status in sweet corn (*Zea mays var saccharata*). Environment and Ecology. 35(4B): 3093-3098.

Swetha, K., Madhavi, M., Pratibha, G. and Ramprakash, T. (2015). Weed management with new generation herbicides in maize. Indian Journal of Weed Science. 47(4): 432-433.

Tagoura, R.M.H. and Ibrahim, S.M. (2017). Effect of the foliar enrichment and herbicides on maize and associated weeds irrigated with drainage water. Annals of Agricultural Sciences. 62: 183-192.

Takim, F.O., Fadayomi, O. and Ekeleme, F. (2014). Influence of cropping system and weed management practices on weed emergence, growth of weeds, yield of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.). Acta Agronomica Hungaria. 45(1): 10-15.

Tarundeep, K., Simerjeet, K. and Bhullar, M.S. (2016). Management of complex weed flora in maize with post emergence herbicides. Indian Journal of Weed Science. 48(4): 390-393.

Tikendra, K.Y., Choudhary, R.S., Roshan, C. and Kaushal, K. (2017). Studies of weed management practices on weed dynamics and yield of maize (*Zea mays* L.). International Journal of Chemical Studies. 5(4): 1957-1960.

Tiwari, D.K., Paradkar, V.K., Gour, C.L. and Rajiv, D. (2017). Evaluation of the bio-efficacy of topramezone against weed control of maize (*Zea mays* L.). Technofame- A Journal of Multi Disciplinary Advance Research. 41(6): 41-44.

Tiwari, D.K., Paradkar, V.K., Dubey, R. and Dwivedi R.K. (2018). Bio efficacy of post-emergence herbicide topramezone against weed control of maize (*Zea mays* L.). International Journal of Agriculture Sciences.

Triveni, U., Sandhya Rani Y, Patro, T. and Lakshmi, M.B. (2017). Effect of different pre and post emergence herbicides on weed control, productivity and economics of maize. Indian Journal of Weed Science. 49(3): 231-235.

Tyagi, S., Mandal, S.K., Rajesh, K. and Sunil, K. (2018). Effect of different herbicides on soil microbial population dynamics in *rabi* maize (*Zea mays* L.). International Journal of Current Microbiology and Applied Sciences. 7: 3751-3758.

Varshitha, V., Ramesh Babu, P., Nirmalnath, J., Asha, M.J. and Roopashree, M. (2019). Effect of early post emergent herbicides/ herbicide mixtures on weed control and soil biological activity in maize. International Journal of Current Microbiology and Applied Sciences. 8(3): 422-430.

Veeresh, H., Sanjay, M.T., Prasad, TV.R., Murthy, K.N.K., Basavaraj, K. and Shruthi, M.K. (2014). Effect of new herbicide molecules on yield, soil microbial biomass and their phytotoxicity on maize (*Zea Mays* L.) under irrigated conditions. The Bio scan. 9(3): 1127-1130.

Yakadri, M., Rani, P.L., Prakash, T.R., Madhavi, M. and Mahesh, M. (2015). Weed management in zero till maize. Indian Journal of Weed Science. 47(3): 240-245.