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Studies on integrated weed management practices in maize- A review

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ABSTRACT

Worldwide yield losses in maize due to weeds are estimated to be around 37%. Weeds reduce crop yield by competing for light, water, nutrients and CO_2, interfere with harvesting and increase the cost of cultivation. The predominant weed flora were *Echinochloa crusgalli* L. and *Cynodon dactylon* L. among monocots; *Cyperus rotundus* L. among sedges; and *Amaranthus viridis* L., *Digera arvensis* L., *Portulaca oleracea* L., *Alternenthara sessili* L. and *Trianthema spp*. among dicots in India. The infestation of these weeds is increasing day by day in the maize growing belt of the state especially where the farmers are using atrazine year after year. New herbicides with broad spectrum of weed control are highly essential for effective control of grasses, sedges and broad leaved weeds. So, in order to widen the weed control spectrum, it is desirable to use tank mix combinations of two herbicides having different mode of action and integrated weed management practices for better weed control.

Key words: Maize, Nutrient uptake, Weed flora, Weed management, WCI, Yields.

Cereals are dominate in world agricultural production because they are directly or indirectly provide the large portion of human subsistence. These crops are most important source of concentrated carbohydrate and happened to be a cheap source in terms of afford and costs of production. Among the cereals, Maize (*Zea mays* L.) is the world's widely grown cereal crop and primary staple food-crop in many developing countries (Kumar *et al*., 2015a,b and Ram *et al*., 2017). It is the 3rd major food-grain crop after rice and wheat in India. Maize is known as 'Queen of Cereals' because of its high production potential and wider adaptability (Kumar *et al*., 2016 and Kumar *et al*., 2017a). The cereals occupy about 54 per cent of the total cropped area of which maize occupies about 3.61 per cent of the total cropped area of India. In India, it is cultivated on an area of 8.69 million ha with a production of 21.81 million tonnes and the productivity of 2509 kg/ha contributing nearly 9.0 per cent of the total food-grains production in the country (Anonymous, 2016). The major maize producing states are Karnataka, Rajasthan, Andhra Pradesh, Bihar, Maharashtra and Uttar Pradesh, which shared 60 per cent of area and 70 per cent production in the country (Singh *et al*., 2017a and Trivedi *et al*., 2017).

Weed management in maize can be highly sophisticated due to wider row spacing. Mechanical control of weeds growing between the rows is labour intensive. Hence weed control in developed countries is done by using herbicides. Herbicides weed control is an important alternative to manual weeding because it is cheaper, faster and gives better weed control (Chikoye *et al*., 2005 and Kumar *et al*., 2017b). Management of weeds is considered to be an important factor for achieving higher productivity as weed problem is more severe during continuous rains in early stages of maize growth which cannot be controlled by traditional and cultural practices alone due to too much wetness. Weeds reduce maize yield from 33-50% depending upon weed species and density (Sharma *et al*., 2000). Weeds compete with crops for light, moisture, space and plant nutrients and consequently interfere with the normal growth of crops. It is known that there is a critical crop-weed competition period with grain losses reaching between 28 and 100% if weeds are not controlled (Teasdale and Mohler, 2000 and Kumar *et al*., 2017b). Control of weeds in maize is, therefore, very important for obtaining higher productivity. Weed control practices in maize resulted in 77 to 96.7% higher grain yield than the weedy check (Tesfay *et al*., 2014 and Yadav *et al*., 2018). Hence, systematic investigations on these aspects are important; therefore, this review chapter was prepared.

Major Weeds Flora Associated with Crop: Sanodiya *et al*. (2013) found that predominant weeds under monocot

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were *Echinochloa colona* (15.4%), *Digiteria sanguinalis* (13.1%), *Cyperus rotundus* (16.2%) and *Commelina communis* (14.0%). *Phyllanthus niruri* (14.4%) and *Eclipta alba* (13.6%) were prominent among dicot weeds. Many other minor weeds in small intensity (13.3%) were also present in maize ecosystem at 60 DAS stage. Ram *et al*. (2017) carried out an field study on maize at Hyderabad and the major weeds species namely; *Parthenium hysterophorus, Melilotus alba, Cyperus rotundus, Trianthema portula-castrum, Dactyloctenium aegyptium, Cynodon dactylon, Digera muricata, Amaranthus viridis, Commelina benghalensis, Eragrostis cilianensis, Chenopodium album, Trichodesma indicum, Digitaria sanguinalis, Euphorbia geneculata* and *Echinochloa colona* were found comprising of broadleaved weeds 49 per cent, grasses 44 per cent and 7 per cent sedges.

Critical period of crop weed competition: The critical period of crop weed competition depends on the density, competitiveness and emergence periodicity of the weed population (Evans *et al.*, 2003 and Bystro *et al*., 2012). Gopinath and Kundu (2008) reported that the weed competition during the early crop growth stages should be low to achieve higher yields. Reduction in crop-weed competition resulted in increase in the dry matter accumulation of maize, which subsequently lead to increased yield attributes and grain yield as reported by Mundra *et al*. (2003). Application of pre-emergence herbicide during early growth stages followed by post-emergence weed control measures resulted in reduced crop-weed competition and markedly improved the weed control efficiency which subsequently produced higher grain yield in maize (Pandey *et al.*, 2001).

Yield losses due to weeds: Bahar *et al*. (2009) opined that uncontrolled weed growth resulted in 73.4% reduction in grain yield of *kharif* maize in silty clay loam soil of Kashmir. Among the factors responsible for low yields in maize, severe infestation by weeds due to wider row spacing coupled with frequent rains in rainy season inflicting huge yield losses up to 68.9% (Walia *et al*., 2007) and 28-100% (Patel *et al*., 2006). Season long weed competition in maize reduced the grain yields by more than 90% as reported by Dalley *et al*. (2006). The yield losses in maize due to weeds range from 40% to 80% as reported by Reddy and Tyagi (2005). Weeds cause significant yield loss worldwide with an average of 12.8% when weed control methods are applied and 37% without any weed control (Oerke and Dehne, 2004). However, Dogan *et al*. (2006) reported that weeds reduced the corn yield by 43% when allowed to compete with crop from sowing to harvest.

Effect of weed management practices on weed density and dry weight: Amin *et al*. (2008) observed that application of primextra gold 720 SC (s-metolachlor + atrazine) @ 0.98 l/ha was recorded minimum weed density at 25 DAS and 75 DAS (31.75 and 46.25 g/m^2, respectively) and biomass (153.0 and 174.50 g/m^2, respectively) as compared to other herbicidal treatments. Subbulakshmi *et al*. (2009) reported that lowest number of grasses, broad leaved, total weed density and weed dry weight were observed with pre-emergence herbicide application of atrazine 0.5 kg/ha followed by hand weeding at 20 DAS. However, 40 DAS hand weeding recorded lower grasses, broad leaved weed, total weed density and weed dry weight. From Dharwad recorded significantly lower dry weight of weeds which was on par with mechanical weeding. Nadiger *et al*. (2013) conducted an field experiment at Dharwad. They recorded the opined that application of oxyfluorfen 0.10 or 0.15 kg/ha and atrazine @ 1.25 kg/ha as pre-emergence + one intercultivation at 30 DAS + one hand weeding at 45 DAS significantly reduced the total weed density and weed dry weight over all weed management treatments except weed free check. Shankar *et al*. (2015) results revealed that significantly lower density and dry weight of weeds/m^2 was recorded with Atrazine @ 1.25 kg or Pendimethalin 2.5 lit./ha as to other chemical weed management treatments. However, which were on par with weed free check and significantly lower weed dry weight/m^2 was recorded in pendimethalin5 lit./ha compared to rest of the treatments.

Samant *et al*. (2015) based on his study carried out at Krishi Vigyan Kendra, Angul, Odisha during *kharif* 2013-14 reported that all the weed management practices in maize significantly reduced the weed density and weed dry weight than weedy check at 60 DAS which was followed by pre-emergence application of pendimethalin 30% EC @1.5 kg/ha and pendimethalin 30% EC @ 1.0 kg/ha *fb* one hand weeding at 30 DAS. Singh *et al*. (2015) they observed that *Dactyloctenium agyptium* weed was difficult to control by pre-emergence application of either atrazine 1.0 kg/ha or metribuzin 0.25 kg/ha, however it was effectively controlled by preemergence application of metribuzin 0.25 kg/ha followed by one hand weeding at 21 DAS. Dutta *et al*. (2016) reported that among herbicides, atrazine 2.0 kg/ha either and atrazine 1.0 kg/ha + HW at 30 DAS showed its superiority by lowering the density and dry weight of grass, sedge and broad-leaf weeds as compared to that of metribuzine at all the stages of crop growth.

Tagoura and Ibrahim (2017) while working on maize found that two hand hoeing treatment exerted the highest decrease in total dry weight of weeds followed by metribuzin (720 g/ha), oxadiagyl (600 g/ha), fluroxypyr (0.48 l/ha) and bentazon (1.8 l/ha), respectively at 60 and 80 days after sowing compared with other weed management treatments. Imoloame (2017) carried out an field experiment on maize crop reported that application of metolachlor + atrazine and pendimethalin + atrazine at 1.0 + 2.0 kg *a.i.*/ha + supplementary hoe weeding along with two hand weeding at 3 and 6 week after sowing was significantly reduce weed dry matter, weed density and weed cover proves the

effectiveness and efficacy against the weed flora. Simić *et al*. (2017) reported that application of herbicides mixer (s-metolachlor 960 g/ha + mesotrione 120 g/ha) to control grass and broadleaved weeds as preemergence was recorded lowest biomass (87.7 g/m^2) as compared to weedy check. Sivamurugan *et al*. (2017) reported that application of pendimethalin @ 1.0 kg *a.i.*/ha as preemergence *fb* atrazine (0.75 kg *a.i.*/ha) + 2,4-D amine (0.4 kg *a.i.*/ha) at 25 DAS as PoE recorded significantly the lower grassy weed count (4.93 m^2) and weed dry weight (16.60 g/m^2) on 50 DAS and it was statistically on par with the application of atrazine @ 1.5 kg *a.i.*/ha as preemergence *fb* Tembotrione @ 120 g *a.i.*/ha as PoE at 25 DAS. However, regarding sedges, application of atrazine @ 1.5 kg *a.i.*/ha as preemergence *fb* tembotrione@ 120 g *a.i.*/ha as PoE at 25 DAS recorded significantly the minimum weed count (1.06/m^2) and weed dry weight (0.81 g/m^2) on 50 DAS and it was comparable with application of pendimethalin (1.0 kg *a.i.*/ha) as pre emergence *fb* atrazine (0.75 kg *a.i.*/ha) + 2,4-D amine (0.4 kg *a.i.*/ha) at 25 DAS as PoE.

Soren *et al.* (2018) reported that the lowest weed density and dry weight were recorded by 2,4-D Ethyl Ester 38% EC @ 1.1 kg/ha followed by 2,4 D Ethyl Ester 38% EC @ 1.0 kg/ha at different growth stages. Two hand weedings at 20 and 40 DAS significantly recorded the lowest weed density and dry weight at 30, 45 and 60 DAS compared to rest of the treatments. An investigation was carried out at Varanasi by Gaurav *et al*. (2018) found that among the herbicidal treatments, weed free treatments performed better than all the herbicidal treatments in respect to biomass of weeds. Among the herbicidal treatments, sequential application of atrazine 1.0 kg *a.i.*/ha (PE) followed by 2, 4-D at 30 DAS (0.5 kg *a.i.*/ha PoE), observed the lowest weed dry biomass when compared to tembotrione 100 g *a.i.*/ha (PoE), tembotrione 125 g *a.i.*/ha (PoE) and it was at par with atrazine 1.0 kg *a.i.*/ha followed by one hand weeding at 30 DAS and pendimethalin 1.0 kg *a.i.*/ha (PE) followed by one hand weeding at 30 DAS, respectively. Yadav *et al*. (2018) carried out a field experiment at Jhabua (MP) found that the lowest density of sedges (7.50, 9.15 and 13.10 no. m^2 at 30, 45 and 60 DAS, respectively), grasses (20.60, 29.95 and 38.20 no. m^2 at 30, 45 and 60 DAS, respectively) and BLWs (28.80, 39.60 and 49.0 no. m^2 at 30, 45 and 60 DAS, respectively) were recorded with application of saflufenacil 68 g/l+diamethanamid-P 600 g/l EC (85 +750).

Effect of weed management practices on weed control efficiency and weed index: Chopra and Angiras (2008) observed that application of atrazine as preemergence 1.5 kg *a.i.*/ha recorded highest WCE (83.55%) over acetachlor @ 1.25 and 0.75 kg *a.i.*/ha. Highest weed control efficiency (90.68%) was recorded with pendimethalin @ 1050 g *a.i.*/ha as PE *fb* manual hoeing twice at 20 and 40 DAS, which was followed by tank mix application of pendimethalin + prometryn @ 1225 g *a.i.*/ha (Tahir *et al.*, 2009). Subbulakshmi *et al*. (2009) reported that highest weed control efficiency was recorded by hand weeding on 20 and 40 DAS, which was followed by preemergence application of atrazine 0.5 kg/ha followed by hand weeding on 40 DAS. Hawaldar S and Agasimani (2012) reported that weed free treatment gave the highest weed control efficiency and weed index followed by atrazine @ 1.0 kg/ha PE + interculture operation at 30 DAS and both treatment were found statistically superior to rest of the treatments. Sanodiya *et al*. (2013) observed that maximum WCE and weed index was with 2 hand weeding closely followed by alachlor 2.5 kg/ha + hand weeding at 30 DAS, atrazine 1.0 kg/ha + hand weeding at 30 DAS, combined application of atrazine 0.75 kg/ ha + pendimethalin 0.75 kg/ha and atrazine 0.75 kg/ha + alachlor 2.25 kg/ha during the experimentation. Rani and Sagar (2013) results revealed that higher weed control efficiency (88.8%) was recorded with hand weeding twice at 20 and 40 DAS, which was at par with sulfosulfuron @ 15 g *a.i.*/ha + imazethapyr @ 25 g *a.i.*/ha as preemergence with hand weeding at 40 DAS (2.94 no/m^2, 2.15 g/m^2 and 88.8%, respectively). Singh *et al*. (2015) found that maximum weed index with maize + cowpea intercropping and lowest weed index wasat par with metribuzin + 1 HW and atrazine PE + 1 HW treatment combination.

Rao *et al*. (2016) reported that highest weed index (45.8%) was recorded in weedy check. While the lowest weed index was observed with hand weeding at 20 and 40 DAS which was statistically at par with pendimethalin @ 1.0 kg *a.i.*/ha (PE) *fb* topramezone spray @ 25 g a.i/ha at 20 DAS (13.9 and 18.1, respectively). Ehsas *et al*. (2016) observed that application of preemergence application of atrazine @ 0.75 kg/ha + pendimethalin @ 0.75 kg/ha recorded highest weed control efficiency (82.97%) followed by preemergence application of alachlor @ 1.5 kg/ha + atrazine @ 0.50 kg/ha. Dutta *et al*. (2016) reported that significantly higher weed control efficiency (88.32%) and lower weed index (4.63%) was recorded in weed free followed by atrazine @ 2.0 kg/ha either and atrazine 1.0 kg/ha + HW at 30 DAS as compared to other treatments. Kumar *et al*. (2017b) observed that application of CT-acetochlor @ 3.0 lit a.i /ha as PE recorded higher weed control efficiency (87.8%) followed by ZT-glyphosate pre plant followed by topramezone+atrazine (40 ml + 500 g a.i/ ha) PoE (84.1%). Soren *et al*. (2018) observed that highest weed control efficiency was recorded in hand weeding twice at 20 and 40 DAS. Among the herbicides 2,4-D Ethyl Ester 38% EC @ 1.10 kg/ha recorded significantly highest weed control efficiency followed by 2,4-D Ethyl Ester 38% EC @ 1.0 kg/ha which were superior to rest of the treatments. Yadav *et al*. (2018) observed that highest WCE of sedges (49.23, 47.07, and 40.53% at 30, 45 and 60 DAS, respectively), grasses (67.63, 57.32 and 52.72% at 30, 45 and 60 DAS, respectively) and BLWs (73.95, 67.91 and

61.42% at 30, 45 and 60 DAS, respectively) were recorded under saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750).

Effect of weed management practices on growth characters of crop: Nadeem *et al*. (2008) recorded maximum plant height (216.70 cm) in manual hoeing and it was statistically at par with foramsulfuron + isoxadifen-ethyl at 1125 g *a.i.*/ha + 3% urea and foramusulfuron + isoxadifen-ethyl at 1125 g *a.i.*/ha alone. Arvadiya *et al*. (2012) the study was conducted at Instructional Farm, Navsari Agricultural University, Navsari concluded that weed free, atrazine 1.0 kg/ha PE + HW at 40 DAS, pendimethalin 1.0 kg/ha as PE + HW at 40 DAS and HW at 20 DAS + inter-culture at 40 DAS were found equally effective in increasing plant height, 50% silking and dry matter accumulation except hand weeding at 20 DAS + inter culturing at 40 DAS for dry matter accumulation but significantly superior to rest of the weed management treatments. The field experiment was conducted by Rani and Sagar (2013) at Tirupati, Acharya N.G. Ranga Agricultural University, on sandy loam soil and observed that taller plants, higher leaf area index and dry matter production was noticed with hand weeding twice at 20 and 40 DAS however, it was comparable with combined preemergence application of sulfosulfuron @ 15 g *a.i.*/ha + imazethapyr @ 25 g *a.i.*/ha with hand weeding at 40 DAS.

Rao *et al*. (2016) was conducted a field experiment at Bapatla on sandy clay loam soil during the *kharif* 2014 to study the effect of preemergence (atrazine @ 1.0 kg a.i/ha and pendimethalin @ 1.0 kg a.i/ha) and post emergence (topramezone @ 25 g a.i/ha) herbicides on growth and yield of maize. Hand weeding at 20 and 40 DAS recorded the highest plant height and dry matter accumulation which was statistically on a par with atrazine @ 1.0 kg *a.i.*/ha *fb* topramezone @ 25 g *a.i.*/ha at 20 DAS and pendimethalin @ 1.0 kg *a.i.*/ha *fb* topramezone @ 25 g *a.i.*/ha at 20 DAS. Ehsas *et al*. (2016) observed that significantly taller plant and maximum dry matter (g/plant) at harvest was recorded with weed free which was statistically at par with preemergence application of atrazine @ 0.75 kg/ha + pendimethalin @ 0.75 kg/ha, weed control through trash mulch (sugarcane trash @ 5 t/ha), preemergence application of atrazine (0.75 kg/ha) and preemergence application of alachlor @ 1.5 kg/ha + atrazine @ 0.5 kg/ha. Kumar *et al*. (2017b) reported that two hand weeding at 15 and 30 DAS being statistically at par with weed control treatments i.e. ZT-Glyphosate pre-plant followed by atrazine + halosulfuran (1.0 kg + 90 g *a.i.*/ha) as PoE and ZT-glyphosate pre-plant followed by topramezone + atrazine (40 ml + 500 g *a.i.*/ha) as PoE recorded significantly higher plant height as compared to the rest of the weed control methods. Sivamurugan *et al*. (2017) observed that weed free practices recorded significantly higher plant height (230.2 cm) and it was comparable with pendimethalin @ 1.0 kg *a.i.*/ha as preemergence *fb* atrazine (0.75 kg *a.i.*/ha) + 2,4-D amine (0.4 kg *a.i.*/ha) at 25 DAS as PoE and atrazine @ 1.5 kg *a.i.*/ ha as preemergence *fb* tembotrione @ 120 g *a.i.*/ha as PoE at 25 DAS.

Effect of weed management practices on yield attributes and yields: Tahir *et al*. (2009) reported that manual hoeing proved superiority among the weed management treatments. Application of pendimethalin @ 1050 g *a.i.*/ha produced significantly higher number of grains/row (38.23), number of grains/cob (565.7), cob length (18.01 cm), 1000-grain weight (527.6 g) and grain yield (7.92 t/ha) as compared to rest of the treatments. Subbulakshmi *et al*. (2009) reported that highest weed grain yield (47.96 q/ha) and stover yield (89.31q/ha) was recorded by hand weeding on 20 and 40 DAS, which was followed by preemergence application of atrazine @ 0.5 kg/ha + one hand weeding on 40 DAS. Hawaldar and Agasimani (2012) found that among the weed management practices weed free proved superiority in respect to yield attributes and yields. Application of atrazine 0.75 kg/ha *fb* 2,4-D 1.0 kg/ha was recorded highest grain yield which was pat par with weed free treatment. Haji *et al*. (2012) reported that significantly higher yield attributes (grains weight/cob and 100-grain weight) and seed yield (5302 kg/ha) was found in atrazine 1.25 kg/ha *fb* glyphosate 2.5 kg/ha over weedy check. However, atrazine 1.25 kg/ha *fb* glyphosate 3.0 kg/ha (5283 kg/ha), standard check i.e. atrazine 1.25 kg/ha +2 intercultivation + 1 hand weeding (4826 kg/ha), atrazine 1.25 kg/ha *fb* paraquat 1.5 kg/ha (4752 kg/ha), atrazine 1.25 kg/ha paraquat 1.0 kg/ha (4791 kg/ha) were at par with treatment.

Kumar *et al*. (2013) reported that in zero tillage maize pre-plant incorporation of glyphosate followed by atrazine + halosulfuron @ (1.0 + 90 g *a.i* ha^{-1}) as PoE resulted in highest grain yield compared to unweeded control. Nadiger *et al*. (2013) reported that significantly higher grain weight (158.17, 164.82 and 159.92 g/plant, respectively), 1000-grain weight (35.01, 36.56 and 34.99 g, respectively) and grain yield (10523, 10827, 10436 kg/ha, respectively) were recorded under oxyfluorfen 0.10 kg/ha which was at par with 0.15 kg/ha and atrazine @ 1.25 kg/ha as pre-emergence + one intercultivation at 30 DAS + one hand weeding at 45 DAS. Sanodiya *et al*. (2013) opined that higher yield attributes and grain (2.25 and 2.20 t/ha) and stover yield (14.09 and 13.83 t/ha) was noted in hand weeding at 20 and 40 DAS followed by atrazine 1.0 kg/ha + hand weed at 30 DAS, than other treatments, respectively. Rani and Sagar (2013) concluded that maximum green cob (13.72 t/ha) and fodder yield (18.04 t/ha) were recorded with hand weeding twice at 20 and 40 DAS which was in parity with preemergence application of sulfosulfuron + imazethapyr with hand weeding at 40 DAS (13.23 and 18.04 t/ha, respectively).

Rao *et al*. (2016) observed that hand weeding twice recorded the highest kernel yield (5974 kg/ha) and stover yield (7837 kg/ha). Among the weed control treatments, application of atrazine @ 1.0 kg a.i/ha *fb* topramezone @ 25 g *a.i.*/ha at 20 DAS and pendimethalin @ 1.0 kg *a.i.*/ha *fb* topramezone @ 25 g *a.i.*/ha at 20 DAS produced significantly higher kernel and stover yield of maize. Dutta *et al*. (2016) reported that twice hand weedings proved its superiority by producing significantly higher values of number of cobs/plant, weight/cob, length/cob and girth/cob compared to the other treatments, except weed free check. Kumar *et al*. (2017b) found that two hand weedings at 15 and 30 DAS being statistically at par with weed control treatments i.e. ZT-Glyphosate pre-plant followed by atrazine + halosulfuran (1.0 kg + 90 g *a.i.*/ha) as PoE and ZT-glyphosate pre-plant followed by topramezone + atrazine (40 ml + 500 g a.i/ha) as PoE recorded significantly higher cob length, cob diameter, grains row/cob, cob weight and test weight and grain yield as compared to the rest of the weed control. Sivamurugan *et al*. (2017) reported that weed free condition practice recorded the highest 100-seed weight, grain and stover yield of maize. This was comparable with application of atrazine @ 1.5 kg *a.i.*/ha as preemergence *fb* tembotrione @ 120 g *a.i.*/ha as PoE at 25 DAS (37.66 g, 6412 and 11328 kg/ha) and application of pendimethalin @1.0 kg *a.i.*/ha as preemergence *fb* atrazine (0.75 kg *a.i.*/ha) + 2,4-D amine (0.4 kg *a.i.*/ha) at 25 DAS as PoE (37.32 g, 6274 and 11102 kg/ha, respectively). Imoloame (2017) results showed that higher yield of maize was produced by metolaclor + atrazine and pendimethalin + atrazine at 1.0 + 2.0 kg *a.i.*/ha plus one supplementary hoe weeding at 6 WAS and two hand weeding at 3 and 6 WAS compared to the other weed control treatments. Kumar *et al*. (2017c) observed that maximum grains/cob, (287.2 and 291.2 2014 and 2015, respectively), grain yield (43.68 and 45.20 q/ha in 2014 and 2015, respectively) an stover yield (82.50 and 54.60 q/ha in 2014 and 2015, respectively) were recorded with the application of tembotrione @ 130 g/ha + surfactant (1000 ml/ha) at 21 DAS which was on par with tembotrione @ 130 g/ha + surfactant (1000 ml/ha) at 14 DAS. Gaurav *et al*. (2018) reported that significantly highest grain (5577 and 5875 kg/ha in 2015 and 2016, respectively) and straw yield (6107 and 6737 kg/ha in 2015 and 2016, respectively) were recorded under the application of atrazine 1.0 kg *a.i.*/ha (PE) followed by 2,4-D at 30 DAS (0.5 kg *a.i.*/ha PoE), than tembotrione 100 g *a.i.*/ha (PoE) and tembotrione 125 g *a.i.*/ha (PoE) and it was statistically at par with atrazine 1.0 kg *a.i.*/ha followed by one hand weeding at 30 DAS and pendimethalin 1.0 kg *a.i.*/ha (PE) followed by one hand weeding at 30 DAS, respectively.

Effect of weed management practices on economics: Amin *et al*. (2008) observed maximum net returns of Rs. 44,335/ha was recorded under primextra gold 720 SC (s-metolachlor + atrazine) @ 0.98 l/ha followed by atrazine (Rs. 33,347/ha). However the minimum net returns of Rs. 30,555/ha was noted in weedy check. Deshmukh *et al*. (2008) reported that preemergence application of atrazine @ 0.75 kg *a.i.*/ha followed by one hand weeding at 45 DAS was recorded higher benefit cost ratio. Arvadiya *et al*. (2012) results revealed that maximum net return of Rs. 88,873 with BCR of 6.72 was realized in atrazine 1.0 kg/ha + HW 40 DAS followed by weed free check with net return of Rs.87,149/ha with benefit cost ratio of 5.66. Haji *et al*. (2012) results revealed that application of atrazine 1.25 kg/ha *fb* glyphosate 3.0 kg/ha and atrazine 1.25 kg/ha *fb* glyphosate 2.5 kg/ha realized higher net return (Rs. 60,702 and 59,139/ha, respectively) and B:C (3.76 and 3.70, respectively). Sanodiya *et al*. (2013) reported that maximum gross returns (Rs. 44,054 /ha) was obtained with weed free treatment closely followed by atrazine 1.0 kg/ha + hand weeding (Rs. 43,140/ha) and alachlor 2.5 kg/ha + hand weeding (Rs. 41,699/ha). However, maximum returns (Rs.17,020 and 16,200/ha) and B:C ratio (1.71 and 1.69) were in combined application of atrazine 0.75 kg/ha + alachlor 2.25 kg/ha closely followed by atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha, respectively. Rani and Sagar (2013) reported that maximum gross returns (Rs. 52,352/ha) was obtained with hand weeding twice at 20 and 40 DAS, which was at par with combined pre-emergence application of sulfosulfuron + imazethapyr with hand weeding at 40 DAS. However, higher net returns (Rs. 37,806/ha) and B:C ratio (3.94) were recorded with the application of sulfosulfuron + imazethapyr as preemergence with hand weeding at 40 DAS which was comparable with hand weeding twice.

Mathukia *et al*. (2014) an field study was carried out at Junagadh Agricultural University, Junagadh during *rabi* 2010-11, results revealed that maximum net returns of Rs. 77926/ha and B:C of 3.14 were realized with weed free treatment, followed by HW and intercultivation at 15 and 30 DAS and atrazine @ 0.5 kg/ha as PE + HW and intercultivation at 30 DAS. Samant *et al*. (2015) observed that maximum net return (Rs. 28,132/ha) and B:C ratio (1.80) was recorded in farmers practice followed by atrazine 1.0 kg/ha (Rs.23,821/ha). Swetha *et al*. (2015) observed that higher net return (62.61 x 10^3 Rs./ha) benefit: cost ratio (3.17) was recorded in tank mix of topramezone + atrazine at 25.2 + 250 g/ha + MSO as PoE (3.17) followed by atrazine as PE followed by intercultivation at 30 DAS. Rao *et al*. (2016) reported that the among the herbicides, maximum gross returns (Rs. 76,977/ha), net returns (Rs. 51,340/ha) and benefit cost ratio (2.0) were recorded under atrazine @ 1.0 kg a.i/ha *fb* topramezone @ 25 g *a.i.*/ha at 20 DAS which was comparable with pendimethalin @ 1.0 kg *a.i.*/ha *fb* topramezone @ 25 g *a.i.*/ha at 20 DAS. Kumar *et al*. (2017b) observed that ZT-glyphosate pre plant followed by atrazine + halosulfuron (1.0 kg +90 g a.i/ha) as PoE produced maximum gross returns of Rs. 89,000/ha and net returns of Rs. 55,767 followed by CT-acetochlor @ 3.0 lit a.i /ha as

PoE (Rs. 85,700 and 55,748/ha, respectively). However the higher benefit cost ratio (1.98) was obtained under ZT-glyphosate pre-plant followed by maize + lathyrus as intercrop. Sivamurugan *et al*. (2017) reported that application of pendimethalin @ 1.0 kg *a.i.*/ha as preemergence *fb* atrazine (0.75 kg *a.i.*/ha) + 2,4-D amine (0.4 kg ai/ha) at 25 DAS as PoE registered the maximum net return (Rs.50,827/ha) and B:C (2.22) which was statistically similar with atrazine @ 1.5 kg *a.i.*/ha as preemergence *fb* tembotrione @ 120 g *a.i.*/ ha as PoE at 25 DAS (Rs. 49,141/ha and 2.08, respectively).

Effect of weed management practices on nutrient uptakes: Mahadevaiah and Sagar (2014) observed that highest uptake of nitrogen, phosphorus and potassium were recorded with preemergence application of atrazine 1.0 kg *a.i.*/ha + one intercultivation at 30 DAS, which was comparable with preemergence application of atrazine + post emergence application of paraquat 0.5 kg *a.i.*/ha at 30 DAS. Samant *et al*. (2015) opined that lowest nutrient depletion by weed was observed in farmers practice (two hand weedings) which was removed 9.14 N, 0.53 P and 9.61 K kg/ha. Among the herbicide treatments preemergence application of atrazine 1.0 kg/ha curtailed removal of N, P and K by weeds to the tune of 87.5, 91.2 and 87.1%, respectively over that of weedy check. Tagoura and Ibrahim (2017) results revealed that two hands hoeing produced the maximum values of protein and oil content followed by in metribuzin (720 g/ha) treatment when the foliar enrichment was used. Kumar *et al*. (2017b) reported that highest uptake of N, P and K (224.7, 46.8 and 146.2 kg/ha, respectively) was recorded in CT-HW at 15 and 30 DAS followed by under ZT-glyphosate pre-plant followed by atrazine + halosulfuron (1.0 kg + 90 g a.i/ha) as PoE (221.4, 46.1 and 145.6 kg/ha, respectively). Gaurav *et al*. (2018) reported that weed management practices significantly influenced the N, P and K removal by weeds and highest was recorded in tembotrione 100 g *a.i.*/ha (PoE) and tembotrione 125 g *a.i.*/ha (PoE). Yadav *et al*. (2018) found that the highest uptake of N, P and K by grain and stover of maize was recorded under weed free which was on par with saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 + 750) and saflufenacil 68 g/l + dimethanamid-P 600 g/l EC (68 + 600), but significantly superior to rest of herbicidal treatments. Gaurav *et al*. (2018) while working on maize reported that highest N, P, K, S and Zn availability in soil was recorded in weed free (hand weedings 20 and 40 DAS). Among the weed management treatments, application of atrazine 1.0 kg *a.i.*/ha (PE) *fb* 2,4-D at 30 DAS (0.5 kg *a.i.*/ha PoE), recorded maximum N, P, K, S and Zn availability in the soil which was comparable with atrazine 1.0 kg *a.i.*/ha followed by one hand weeding at 30 DAS and pendimethalin 1.0 kg *a.i.*/ha (PE) followed by one hand weeding at 30 DAS, respectively. Whereas, weedy check have lowest values of N, P, K S, and Zn availability in soil due to higher weed dry weight and poor crop yield.

REFERENCES

Amin, A., Khan, M.Z., Hassan, G., Marwat, K.B., Rashid, H. and Nawab, K. (2008). Weed control efficiency and economics of pre-emergence herbicides in maize (*Zea mays* L.). *The Asian Aus. J. Plant Sci. Biotech*. **2**: 72-75.

Anonymous (2016). Agricultural Statistics at a Glance, Government of India Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics and Statistics.

Arvadiya, L.K., Raj, V.C., Patel, T.U., Arvadia, M.K. and Patel, A.M. (2012). Effect of plant population and weed management practices on productivity of sweet corn. *Indian J. Weed Sci.* **44**: 167–171.

Bahar, F.A., and Singh, K.N and Malik, M.A. (2009). Integrated weed management in maize (*Zea mays* L.) under different nitrogen levels. *Indian J. Agric. Sci.* **79**: 641-644.

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

Chikoye, D., Udensi, U.E., Lum F.A. (2005). Evaluation of a new formulation of atrazine and metolachlor mixture for weed control in maize in Nigeria. *Crop Prot*. **24**: 1016-1020.

Chopra, P. and Angiras, N.N. (2008). Influence of tillage and weed control methods on weeds, yield and yield attributes of maize (*Zea mays* L.). *Indian J. Weed Sci*. **40**: 47-50.

Dalley, C.D., Bernards, M.L and Kells, J.J. (2006). Effect of weed removal timing and row spacing on soil moisture in corn (*Zea mays* L.). *Weed Techn*. **20**: 399-409.

Deshmuk, L.S. Jathore, R.S. and Raskar, S.K. (2008). Studies on nutrient management in *kharif* maize under rainfed conditions. *Indian J. Weed. Sci.* **40**:87-89.

Dogan, I., Husrev, Meannan, B.B., Ahmet, O.Z. and Ngouzjio, M. (2006). The critical period for weed control in corn in Turkey. *Weed Technol*. **20**: 867-872.

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*). *Indian J. Agron.* **61**: 210-216.

Ehsas, J., 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. *Intern. J. Sci. Environ. Techn*. **59**: 2050-2056.

Evans, S.P., Knezevic, S.Z., Lindquist, J.L., Shapiro, C.A and Blankenship, E.E. (2003). Nitrogen application influence the critical period for weed control in corn. *Weed Sci.* **51**: 408-417.

Gaurav, Verma, S.K., Meena, R.S., Maurya, A.C. and Kumar, S. (2018). Nutrients uptake and available nutrients status in soil as influenced by sowing methods and herbicides in *kharif* maize (*Zea mays* L.). *Intern. J. Agric. Environ. Biotech*. **11**: 17-24.

Gopinath, K.A and Kundu, S. (2008). Effect of dose and time of atrazine application on weeds in maize (*Zea mays* L.) under mid-hill conditions of North Western Himalayas. *Indian J. Agric. Sci.* **48**: 254-257.

Haji, I.D., Hunshal, C.S., Malligwad, L.H., Basavaraj, B. and Chimmad, V.P. (2012). Effect of pre and post emergence herbicides on weed control in maize (*Zea mays.* L.). *Karnataka J. Agric. Sci*. **25**: 392-394.

Hawaldar, S. and Agasimani, C.A. (2012). Effect of herbicides on weed control and productivity of maize (*Zea mays* L.) *Karnataka J. Agric. Sci*. **25**: 137-139.

Imoloame, E.O. (2017). Evaluation of herbicide mixtures and manual weed control method in maize (*Zea mays* L.) production in the Southern Guinea agro-ecology of Nigeria. *Cogent Food Agric*. **3**: 1-17.

Kumar, A., Rana, M.C., Sharma, N. Rana, S.S. (2017c). 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. *Intern. J. Curr. Microbiol. Appl. Sci.* **6**: 2297-2303.

Kumar, B., Kumar, R., Kalyani, S. and Haque M. (2013). Evaluation of economics of different weed management practices in *rabi* maize (*Zea mays* L.). *Trends in Biosciences* **6**: 558-561.

Kumar, B., Prasad, S., Mandal, D. and Kumar, R. (2017b). Influence of integrated weed management practices on weed dynamics, productivity and nutrient uptake of *rabi* maize (*Zea mays* L.). *Intern. J. Curr. Microb. Appl. Sci.* **6**: 1431-1440.

Kumar, R., Bohra, J.S., Kumawat, N. and Singh, A.K. (2015b). Fodder yield, nutrient uptake and quality of baby corn (*Zea mays* L.) as influenced by NPKS and Zn fertilization. *Res. Crops*. **16**: 243-249.

Kumar, R., Bohra, J.S., Kumawat, N., Kumar, A., Kumari, A. and Singh, A.K. (2016). Root growth, productivity and profitability of baby corn (*Zea mays* L.) as influenced by nutrition levels under irrigated eco-system. *Res. Crops*. **17**: 41-46.

Kumar, R., Bohra, J.S., Singh, A.K. and Kumawat, N. (2015b). Productivity, profitability and nutrient-use efficiency of babycorn (*Zea mays*) as influenced of varying fertility levels. *Indian J. Agron*. **60**: 285-290.

Kumar, R., Kumawat, N., Kumar, S., Singh, A.K. and Bohra, J.S. (2017a). Effect of NPKS and Zn fertilization on, growth, yield and quality of baby corn-A review. *Intern. J. Curr. Microb. Appl. Sci.* **6**: 1392-1428.

Mahadevaiah, K. and Sagar, G.K. (2014). Effect of integrated weed management practices on yield, nutrient uptake and economics of baby corn. *Agric. Sci. Digest.* **34**: 303-306.

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). *Adv. Crop Sci. Tech*. **2**: 1-3.

Mundra, S.L., Vyas, A.K and Maliwal, P.L. (2003). Effect of weed and nutrient management on weed growth and productivity of maize (*Zea mays* L.). *Indian J. Weed Sci*. **35**: 57-61.

Nadeem, M.A., Ahmad, R., Khalid, M., Naveed, M., Tanveer, A. and Ahmad, J.N. (2008). growth and yield response of autumn planted maize (*Zea mays* L.) and its weeds to reduced doses of herbicide application in combination with urea. *Pak. J. Bot.* **40**: 667-676.

Nadiger, S., Babu, R. and Kumar, B.N.A. (2013). Bioefficacy of pre-emergence herbicides on weed management in maize. *Karnataka J. Agric. Sci*. **26**: 17-19.

Oerke, E.C. and Dehne, H.W. (2004). Safeguarding production-losses in major crops and the role of crop protection. *Crop Prot*. **23**: 275-285.

Pandey, A.K., Prakash, V., Singh, R.D. and Mani, V.P. (2001). Integrated weed management in maize (*Zea mays* L.). *Indian J. Agron.* **46**: 260-265.

Patel, V.J., Upadhyay, P.N., Patel, J.B. and Patel, B.D. (2006). Evaluation of herbicide mixtures for weed control in maize (*Zea mays* L.) under middle Gujarat conditions. *The J. Agric. Sci*. **2**: 81-86

Ram, P., Sreenivas, G., Leela Rani, P. (2017). Impact of sustainable weed management practices on growth, phenology and yield of *rabi* grain maize (*Zea mays* L.). *Intern. J. Curr. Microb. Appl. Sci.* **6**: 701-710.

Rani, B.S. and Sagar, G.K. (2013). Effect of integrated weed management practices on growth, yield and economics of sweet corn. *Agric. Sci. Digest.* **33**: 52-55.

Rao, C.H.R., Prasad, P.V.N. and Venkateswarlu, B. (2016). Assessment of different herbicides on yield and economics of *kharif* maize (*Zea mays* L.). *Intern. J. Agric. Sci. Res.* **6**: 409-414.

Reddy, D.A. and Tyagi, S.K. (2005). Integrated weed management in maize groundnut cropping system. *Agric. Revi.* **26**: 235-248.

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. *Sch. J. Agric. Veten. Sci*. **2**: 79-83.

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

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. *Intern. J. Sci. Environ. Techn*. **4**: 1540-1545.

Sharma, A.R., Toor, A.S. and Sur, H. (2000). Effect of interculture operations and scheduling of atrazine application on weed control and productivity of rainfed maize (*Zea mays* L.) in Shiwalik foot hills of Punjab. *Indian J. Agric. Sci*. **70**: 757-761.

Simić, M., Dragičević, V. and Brankov, M. (2017). Influence of growing measures on weed interference and water status in maize. *Pestic. Phytomed. (Belgrade)* **32**: 113-120.

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 J. Agric Sci.* **85**: 87-92.

Singh, M., Kumawat, N., Tomar, I.S., Dudwe, T.S. and Sahu, Y.K. (2018). Effect of gibberllic acid on growth, yield and economics of maize (*Zea mays* L.) under Jhabua Hills of Madhya Pradesh. *J. Agri Search.* **5**: 25-29.

Sivamurugan, A.P., Ravikesavan, R., Yuvaraja, A., Singh, A.K. and Jat, S.L. (2017). Weed management in maize with new herbicides. *Chem. Sci. Revi. Lett.* **6**: 1054-105.

Soren, C., Chowdary, K.A., Sathish, G. and Patra, B.C. (2018). Weed dynamics and yield of *rabi* maize (*Zea mays* L.) as influenced by weed management practices. *J. Exp. Bio. Agric. Sci.* **6**(1):150-158.

Subbulakshmi, S., Subbian, P. and Prabhakaran, N.K. (2009). Influence of tillage and weed management practices on weed growth and yield of maize-sunflower cropping system. *Intern. J. Agric. Sci.* **5**: 71-77.

Swetha, K., Madhavi, M., Pratibha, G. and Ramprakash, T. (2015). Weed management with new generation herbicides in maize. *Indian J. Weed Sci.* **47**: 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 *Ann. Agric. Sci.* **62**: 183-192.

Tahir, M., Javed, M.R., Tanveer, A., Nadeem, M.A., Wasaya, S.A.H. and Rehman, J.U. (2009). Effect of different herbicides on weeds, growth and yield of spring planted maize (*Zea mays* L.). *Pak. J. Life Soc. Sci.* **7**: 168-174.

Teasdale, J.R. and Mohler C.L. (2000). The quantitative relationship between weed emergence and the physical properties of mulches. *Weed Sci.* **48**: 385-392.

Tesfay, A., Mohammed, A. and Negeri M. (2014). Management of weeds in maize (*Zea mays* L.) through various pre and post emergency herbicides. *Adv. Crop Sci. Techn.* **2**: 2-5.

Trivedi, V.K., Dimree, S., Meena, R.K. and Chauhan, G. (2017). Efficient nutrient management for high crop yield and quality in maize crop. *Intern. J. Pure Appl. Biosci.* **5**: 711-717.

Walia, U.S., Singh, S. and Singh, B. (2007). Integrated control of hardy weeds in maize (*Zea mays* L.). *Indian J. Weed Sci.* **39**: 17-20.

Yadav, R.K., Kumawat, N., Singh, A., Tomar, I.S., Singh, M. and Morya, J., Kumar, R. and Upadhyay, P.K. (2018). Bio-efficacy of new herbicides in mixture and alone on weed dynamic, yields and nutrient uptake of maize (*Zea mays* L.) under rainfed conditions. *Indian J. Agric. Sci.* **88**: 1123-1128.