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Weed management in zero till-maize

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ABSTRACT

Rainy season maize contributes 85% of the total maize area in India. Among major *Rabi* maize growing States, earlier Andhra Pradesh contributed maximum with 45.5% share. The present review reveals that *Echinochloa colona* L. is the most dominant weed species with importance value index (IVI) of 37.64 followed by *Panicum repens* L. (32.29), *Trianthema portulacastrum* L. (16.33) and *Digera arvensis* L Forsk (13.37). Wider spacing and initial slow growth of maize during the first 3-4 weeks provides enough opportunity for weeds to invade and offer severe competition, resulting in 30-93% yield losses. Among weed management practices, hand weeding twice at 15-21 DAS and 30-42 DAS, and integrated weed management like pre-emergence application of atrazine 1.5 kg/ha, pendimethalin 1.50 kg/ha, atrazine + alachlor 0.75 + 1.25 kg/ha, or alachlor 1.5 kg/ha followed by hand weeding at 30 DAS was found effective. Among sequential applications, atrazine as pre-emergence 1.25 kg/ha, or pendimethalin as pre-emergence 1.5 kg/ha followed by paraquat 0.6 kg/ha at 3 weeks after sowing or atrazine 1.0 kg/ha as pre-emergence followed by topramazone 0.030 kg/ha at 30 DAS were found economical with higher gross returns, net returns and B:C.

Key words: Maize, Weed management, Zero tillage

Maize (*Zea mays* L.) is the third most important cereal after rice and wheat, which is widely grown in the world and used as primary staple food in many developing countries. The world area under maize cultivation was 177 Mha with 967 Mt production in 2013-14. It contributes almost 9% to India's food basket and 5% to world's dietary energy supply. Because of its wider adaptability and high yield potential, it suits best in many cropping systems. Maize is predominantly a rainy season (*Kharif*) crop that constitutes 85% of total maize area in the country. The area under maize cultivation is 9.43 Mha in 2013-14 with productivity, 2.58 t/ha (Director's Review 2015). Maize production in India has grown annually by 5.5% over the last 10 years from 14 mt in 2004-05 to 24.35 MT in 2013-14. In India, the current consumption pattern of maize as poultry-pig-fish feed, human diet, cattle feed, and seed and brewery industry is 52, 24, 11 and 1%, respectively. The renowned Nobel Laureate, Dr. Norman E. Borlaug believed that "The last two decades saw the revolution in rice and wheat, the next few decades will be known for maize era". The demand for maize in Asia is expected to grow in the next 20 years, due to the growth of the livestock and poultry feed industry and Asian consumers shifting towards animal-based diets. The rapid expansion of the biofuel industry in recent years and high fossils energy costs also influence global maize demand and supply. The increasing demand for maize is rapidly transforming cropping systems in certain parts of Asia. Significant shifts from rice monoculture to more profitable rice-maize systems have either occurred or are emerging (IRRI and CIMMYT 2006).

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History of zero tillage

Zero tillage technology was first reported in USA in 1930s and from there spread to many countries of Europe, Australia, Canada, Asia and Africa. In India, research on zero tillage (ZT) for wheat started almost three decades ago (Ekboir 2002). Several State Agricultural Universities tried ZT in the 1970s but their efforts failed due to technical difficulties such as the lack of adequate planting equipment and the difficulty in controlling the weeds chemically. In 1990, Centro Internacional de Mejoramiento de Maiz y Trigo [International Maize and Wheat Improvement Center] (CIMMYT) introduced inverted-T openers and in 1991, a first prototype of the Indian ZT seed drill was developed at GB Pant University of Agriculture and Technology, Pantnagar. After considerable investment of resources and several design changes, the first ZT seed drill was made available for field testing within 12 months. Rice-

Wheat Consortium (RWC) for the Indo-Gangetic Plains and CIMMYT contributed significantly for the widespread adoption of zero tillage at the turn of this century. Zero tillage technology has turned into a great success story and seems to be one of the best technologies after Green Revolution (Singh *et al*. 2010)

Heralding *Rabi* (winter) maize revolution in India

In India, maize is grown during *Kharif* season (June to October) when both drought and water logging occurs, which results in lower production. In order to enhance the production of this crop a collaborative project to introduce maize hybrids in India was taken up with Dr. L.M Humphrey, Agriculture Advisor to the Technical Cooperation Mission of USA. Double cross hybrids, *'Texas 26'*, '*Texas 32*' and '*Dixie 11*' introduced under this project from USA in year 1959, were grown on experimental basis in Bihar state during *Kharif* season. These hybrids could not yield up to the expectation due to heavy rainfall during the crop period which is a usual phenomenon of *Kharif* season. In order to protect the crop from heavy rainfall, maize inbred, single cross hybrids and double cross hybrids were grown in *Rabi* season first time on farmers fields in Bihar in the year 1961.

The results were quite encouraging as the crop was free from incidence of insects, pests and diseases in addition to higher yield as compared to *Kharif* maize. This opened up new vista of *Rabi* maize in the country. Keeping in view the opportunities in *Rabi* season, multi-pronged strategies were adopted such as hybrid seed production along with farmer's field demonstrations resulted in heralding maize revolution in Bihar.

The *Rabi* maize in Bihar state occupied 0.49 Mha area out of a total area of 0.75 Mha during 2013-14. This indicates the acceptance of *Rabi* maize technology by farmers of this state. Later it caught the attention of other states like Andhra Pradesh, West Bengal, Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka, Punjab, *etc*., where it is now being grown successfully (Singh *et al* . 2012).

In India *Rabi* maize is grown on an area of 1.7 Mha with the grain production of 6.67 Mt, and average productivity of 3.93 t/ha (Director's Review 2015). The predominant *Rabi* maize growing states are Andhra Pradesh (45.5%), Bihar (20.1%), Tamil Nadu (9.3%), Karnataka (8.5%), Maharastra (7.7%) and West Bengal (5.3%).

In Andhra Pradesh, *Rabi* maize is grown on an area of 0.44 Mha with production of 2.79 MT, having an average productivity of 6.35 t/ha (Director's Review 2015). The trends in area, production and productivity of maize in *Rabi* season in Andhra Pradesh has shown a remarkable increase with the passing years. Maize occupies more acreage under non-traditional season as well as non-traditional areas of the State, indicating that it is emerging as one of the potential driver for crop diversification. The major cropping systems in Andhra Pradesh are rice-based rotations followed by sorghum, groundnut, cotton, sugarcane and maize systems. Maize systems are dominant in Telangana State during monsoon season, whereas during winter season, maize systems are mainly practised in Krishna and Godavari zones in rice fallows. This shift has become possible due to no-till maize in rice-maize system and cultivation of single cross hybrids.

Zero till-maize in Andhra Pradesh and Telangana

Rice-relay pulse crop is an important crop sequence covering 0.3 Mha in Andhra Pradesh. For the past half decade, the greengram and blackgram were subjected to yellow vein mosaic and *Cuscuta* problem. In addition to this, since 2003 onwards in Krishna delta of Andhra Pradesh, due to late release of water, transplanting of rice is delayed and ultimately timely sowing of blackgram as relay crop is not possible. Therefore, farmers are switching over to non-traditional crop like maize in rice fallows as an alternative to blackgram. Under the emerging and potential crop sequence (rice-maize) in coastal region of Andhra Pradesh, the conventional tillage for planting maize under heavy textured soil of rice needs 25-30% higher energy for field preparation which limits the farm profitability and delays maize sowing leading to lower productivity. Generally rice is harvested during second fortnight of November. In case of zero tillage under rice-maize rotation, the farmers can sow maize in time. Further no till maize in rice fallow demonstrated a potential benefit of saving on cost of production ranging from Rs. 3800-5500/ha.

In the conventional rice-maize cropping system, due to efficient land preparation after rice, the problem of rejuvenation of rice stubble was not encountered and initial weed problem is solved with pre-emergence application of atrazine. In rice-zero till maize due to sowing of maize crop after rice harvest, wide spacing, erect and slow early growth problems of weed has become acute. But, in zero till system residues, when retained on the soil surface, serve as physical barrier for emergence of weeds, moderate the soil temperature, conserve soil moisture, add organic matter and improve the nutrient-water interactions.

Weed flora

In clay loam soils of Guntur (Andhra Pradesh), Rao *et al.* (2009) reported the dominant weed flora as *Echinochloa colona* (L.) Link (41%), *Dinebra retroflexa* (Vahl) Panzer (4%), *Panicum repens* L. (3%) and *Cynodon dactylon* (L.) Pers. (2%), *Leptochloa chinensis* (L.) Nees (5%) (grasses), *Cyperus rotundus* L. (5%) (sedges), *Chrozophora rottleri* (Geisel) A. Juss. Ex Spreng. (15%), *Trianthema portulacastrum* L. (13%), *Digera arvensis* (4%), *Merremia emerginata* (Burm. f.) Hall. F. (3*%), Phyllanthus niruri* (3%) and *Euphorbia hirta* L. (2%) (broad-leaved weeds). Mukundam *et al.* (2011) from clay loam soils of Bapatla reported that *C. rotundus* and dicots *T. portulacastrum*, *D. arvensis*, *P. niruri* and *C. dactylon* among grasses were most dominant. In clay loam soils of Warangal, *E. colona* (13%), *D. retroflexa* (11%), *P. repens* (8%) and *L. chinensis* (7%) among the grasses, *C.rotundus* L. (8%) among sedges and *C. rottleri*. (11%), *T. portulacastrum* (9 %), *D. arvensis* (9%), *M. emerginata* (12%), *P. niruri* (3%) and *E. hirta* (9%) among the broad-leaved weeds (Reddy *et al.* 2012). In another study, *E. colona* among the grasses, *C. rotundus* among the sedges, *Ageratum conizoides* and *T. portulacastrum* were the predominant broad-leaved weeds observed in sandy loam soils of Hyderabad (Parameshwari 2013). Weed survey for three years in Krishna zone of Andhra Pradesh revealed that zero till sown maize crop was infested with a total of 21 weed species, of which 7 were grasses, 3 sedges and 11 broad-leaved weeds. Among the weeds, *E. colona* was the most dominant species with IVI of 37.64 followed by *P. repens* (32.29), *T. portulacastrum* (16.33), *D. arvensis* (13.37) (Kiran and Rao 2014). In sandy loam soils of Rajendra Nagar during *rabi* 2014, the predominant weed flora observed in zero tillage maize during crop growing season at 30 DAS were *C. rotundus, E. crusgulli, Paspalum distichum, T. portulacastrum, Parthenium hysterophorus, Sonchus oleraceus, Acalypha indica and Eclipta alba* (Annual Report 2014).

Critical period of weed competition and yield loss

The critical period is useful in defining the crop growth stage which is most vulnerable to weed competition. In practice, the critical period is defined as a number of days after crop emergence during which crop must be weed free in order to prevent yield losses more than 5%. Based on this approach critical period for maize ranges from 1 to 8 weeks after the crop sowing (Thomas and Allison 1975). Wider spacing and slow growing nature of the crop during the first 3-4 weeks provide enough opportunity for weeds to invade and offer severe competition resulting in 30-100% yield reduction (Sandhu *et al.* 1999). Yield losses of 77.4%, 44.2% and 38.4% were observed in maize due to grasses, non-grassy weeds and sedges, respectively (Pandey *et al*. 2002). Losses due to weeds under zero till sown condition in Telangana state and Andhra Pradesh varied from 30 to 93%. In clay loam soil of Guntur, unchecked weed growth caused a yield loss of 43% due to severe weed competition (Rao *et al.* 2009). But, Mukundam *et al.* (2011) reported a yield reduction of 30% with unweeded check treatment in clay loam soils of Bapatla. In another study from clay loam soil of Warangal, Reddy *et al.* (2012) reported a yield loss of 76% due to season-long crop-weed competition. Yield reduction of as high as 93% was observed due to uncontrolled weed growth during entire crop growth season from sandy clay loam soils of Kampasagar (Telangana) (Pasha *et al.* 2012). In sandy loam soils of Hyderabad (Telangana State) under zero till conditions, a significant reduction in grain yield by 69.7 and 70.34% was noticed during 2011 and 2012, respectively (Parameswari 2013). A yield reduction of 50% was observed due to competitive stress of weeds from zero till sown maize during *Rabi* 2014 under Rajendra nagar conditions of Hyderabad (Annual Report 2014).

Rice stubble rejuvenation and weed growth

In rice-zero till maize, the removal of apical dominance due to rice harvest stimulated the lower buds. The wider spacing and initial slow (3-4 weeks) growth of maize maintain high soil moisture, which promotes both rice stubble rejuvenation and first flush of weeds. These problems were not seen in the traditional rice-fallow pulse sequence due to high seed rate, emergence and development of pulse seedlings prior to removal of apical dominance by rice harvest. Consequent to lower moisture regimes (as the pulse crop raised on receding soil moisture) and ephemeral crop growth nature, the rejuvenation of rice stubbles and first flush of weeds did not have any impact on pulse crops. Short duration rice variety promoted more rejuvenation of rice stubbles than medium and long duration varieties (Table 1). On the other hand, higher weed growth and dry matter was recorded in long duration varieties when compared to medium and short duration varieties.

Among herbicides, paraquat spray on rice stubbles controlled rice stubble rejuvenation but was less effective in controlling first flush of weeds in zero-till sequential maize. Immediately after rice harvest, consequent to removal of apical dominance, the lower buds were stimulated and spray of paraquat

Table 1. Sprouted rice stubble (%) and weed dry matter (g/m²) in zero-till maize as affected by treatments (mean of two years)

Treatment	Sprouted rice stubble (%)	Weed dry matter (g/m²)
Kharif rice variety		
Tellahamsa	21.14	16.88
Early Samba	17.54	21.45
Samba Mahsuri	14.99	26.70
LSD (P=0.05)	2.33	2.12
Rabi cropping system		
Maize without herbicide	32.47	35.97
Maize with atrazine	13.12	12.66
Maize with paraquat	8.08	16.40
LSD (P=0.05)	3.17	3.31

Source : Mukundam *et al.* (2011)

instantly killed the emerging cells in the bud and inhibited their growth and rejuvenation. As paraquat was adsorbed by soil particles, there was no control of first flush of weeds.

Weed growth and dynamics

Reddy *et al.* (2012) reported the lowest density (no./m²) and dry weight (g/m²) of grasses (1.0 and 1.0, respectively), sedges (9.0 and 2.0, respectively) and broad-leaved weeds (1.0 and 0.5 respectively) at 30 DAS with tank mix application of atrazine + glyphosate (0.75 + 0.8 kg/ha). Glyphosate (1.6 kg/ha) was found superior to atrazine (1.5 kg/ha) and paraquat (1.5 kg/ha) for density, dry weight of weeds and weed-control efficiency. In Guntur, pre-emergence application of atrazine 1.5 kg/ha followed by (*fb*) hand weeding at 30 DAS recorded the lowest weed dry weight and highest weed control efficiency (WCE) at 60 DAS and harvest. In clay loam soils of Bapatla, two hand weedings at 3 and 6 WAS and intercultivation with power weeder at 4 WAS recorded significantly lowest weed density and dry-matter. Likewise, pre-emergence application of atrazine 1.25 kg/ha in combination with paraquat 0.6 kg/ha at 3 WAS recorded lower weed density (13.67 m²) and dry-matter. Pendimethalin 1. 5 kg/ha + paraquat 0.6 kg/ha was found similar with weed free check and intercultivation with power weeder (Mukundam *et al.* 2011). From sandy clay loam soils of Kampasagar (Telangana State), Pasha *et al.* (2012) reported that pre-emergence application of atrazine 1.25 kg/ha + paraquat 0.75 kg/ha were found effective in reducing weed density (3/m²) and weed dry-matter (7 g/m²). Similarly effective treatments were pre-emergence application of atrazine 1.25 kg/ha + glyphosate 0.5 kg/ha (97.6%), atrazine as post-emergence 1.0 kg/ha (92.4%) and atrazine as pre-emergence 1.25 kg/ha (92.0%), pre emergence application of atrazine 1.0 kg/ha *fb* topramazone 0.030 kg/ha at 30 DAS due to higher WCE, increased growth and yield of zero till maize (Parameswari 2013). At Hyderabad, (Telangana), hand weeding twice at 20 and 40 DAS and pre-emergence application of oxyfluorfen 0.15 kg/ha + paraquat 0.60 kg/ha treatment at 30 DAS, 60 DAS and 120 DAS was found effective (Annual Report 2014).

Growth and yield of zero-till maize

In clay loam soils of Guntur Rao *et al* (2009) were the first to conduct the work on zero tillage maize in Andhra Pradesh (India) without using non selective herbicides. Among all the weed control treatments hand weeding twice at 15 and 30 DAS recorded significantly higher plant height (245 cm) and crop dry matter (398 g). Among herbicides, pre-emergence application of atrazine 1.5 kg/ha *fb* hand weeding (HW) at 30 DAS or pre-emergence application of atrazine 1.5 kg/ha alone recorded higher plant height and dry matter over unweeded check at all stages of crop growth. Experimental results of Mukundam *et al.* (2011) under clay loam soil revealed that, the maximum plant height of maize was noticed with conventional tillage than that under zero tillage. According to studies of Parameswari (2013), among different crop establishment methods significantly higher plant height, dry matter production of maize was obtained when maize was grown after transplanted rice under zero till condition. Higher plant height and crop dry matter was observed with HW twice at 20 and 40 DAS and it was *fb* pre-emergence application of atrazine 1.0 kg/ ha *fb* topramezone 0.030 kg/ha. In clay loam soil of Hyderabad under Rajendranagar conditions (Telangana) the highest crop dry matter was noticed with HW twice at 20 and 40 DAS and was on a par with pre-emergence application of atrazine 1.0 kg/ha + paraquat 0.60 kg/ha and pre-emergence application of oxyfluorfen 0.150 kg/ha + paraquat 0.60 kg/ha (Annual Report 2014). In clay loam soils of Guntur Rao *et al.* (2009), recorded the highest maize yield (10.53 t/ha) with HW twice at 15 and 30 DAS. The increased yield in these treatments was owing to higher WCE and increased crop growth and number of seeds/ cob. In another study, either two HW at 3 and 6 WAS or intercultivation with power weeder at 4 WAS recorded significantly higher grain yield under conventional and zero tillage methods. Among the herbicides sequential application of either atrazine as pre-emergence 1.25 kg/ha *fb* paraquat 0.6 kg/ha at 3 WAS or pendimethalin as pre-emergence 1. 5 kg /ha *fb* paraquat 0.6 kg /ha at 3 WAS (Srividya *et al.* 2011). Reddy *et al.* (2012), who conducted experiment with herbicides alone and tank mix application of selective and non selective herbicides showed that, the grain yield obtained with tank mix application of atrazine + glyphosate (5.25 t/ha) was 170 and 70% more than weedy check and sole atrazine, respectively. In sandy clay loam soils of Kampasagar (Telangana), Pasha *et al*. (2012) reported, tank mix application of atrazine 1.25 kg/ha + paraquat 0.75 kg/ha as pre-emergence produced significantly higher grains/cob, cob diameter and 100 grain weight than other herbicides. Comparable grain yields were recorded with atrazine alone as pre-emergence 1.25 kg/ha (6.7 t/ha) and atrazine 1.25 kg/ha + glyphosate 0.5 kg/ha (7.0 t/ha) as pre emergence application. Under sandy loam soil of Hyderabad, two HW at 20 and 40 DAS resulted in highest yield attributes and yield , followed by pre-emergence application of atrazine 1.0 kg/ha *fb* topramezone 30 g/ha at 30 DAS and atrazine 1.0 kg/ha as pre-emergence alone (Parameswari 2013). Under sandy clay loam soils of Rajendranagar, significantly higher grain yield (5.63 t/ha) and stover yield (6.11 t/ha) was obtained with HW twice at 20 and 40 DAS and was at par with either tank mix pre-emergence application of atrazine 1.0 kg/ha + paraquat 0.60 kg/ha or oxyfluorfen 0.15 kg/ha + paraquat 0.60 kg/ha (Annual Report 2014).

Nutrient uptake

Under irrigated conditions of clay loam soils of Bapatla, Srividya *et al.* (2011) reported that, pre-emergence application of atrazine 1.5 kg/ha or pendimethalin 1.5 kg/ha *fb* paraquat 0.6 kg/ha at 3 WAS recorded significantly lower N, P and K uptake by weeds over application of atrazine or pendimathalin alone. Parameswari (2013) observed that the nutrients depletion by weeds was reduced and crop uptake was enhanced when maize was grown after transplanted rice under zero till condition. The application of atrazine 1.0 kg/ha pre-emergence *fb* topramazone 0.030 kg/ha at 30 DAS was found effective in reducing nutrient uptake by weeds.

Economics

Rao *et al*. (2009) recorded highest gross and net monetary returns and benefit: cost ratio with two HW at 15 and 30 DAS and with pre-emergence application of atrazine 1.5 kg/ha *fb* HW at 30 DAS. In clay loam soils of Warangal, tank mix application of atrazine + glyphosate (0.75+ 0.8 kg/ha) gave the maximum net returns (₹ 29,350/ha) and benefit: cost ratio (1.71) followed by atrazine + paraquat (0.75+0.75 kg/ha) due to the broad-spectrum control of weeds. Amongst weed management practices evaluated, the highest B:C ratio was registered with application of atrazine 1.0 kg/ha *fb* topramezone 0.030 kg/ha at 30 DAS in zero till maize (Parameswari 2013). Higher gross returns, net returns and B.C ratio (88,570, 50820 and 2.35) was obtained with HW twice at 20 and 40 DAS. This was closely followed by pre-emergence application of atrazine 1.0 kg/ha + paraquat 0.60 kg/ha (77915, Rs 45905 and 2.43), pre-emergence application of oxyfluorfen 0.150 kg/ha + paraquat 0.60 kg/ha (77747, Rs 45135 and 2.38) and early post-emergence application of atrazine 1.0 kg/ha (74733, 43763 and 2.41).

Conclusion

Among IWM practices, pre-emergence application of atrazine 1.5 kg/ha *fb* HW at 30 DAS, pendimethalin 1.50 kg/ha *fb* hand weeding at 30 DAS, atazine + alachlor (0.75 + 1.25 kg/ha) *fb* hand weeding at 30 DAS, or alachlor 1.5 kg/ha *fb* hand weeding was more effective against weeds and more economical in maize. Among the sequential herbicide applications, atrazine pre-emergence 1.25 kg/ha *fb* paraquat 0.6 kg/ha at 3 WAS, pendimethalin pre-emergence 1.5 kg/ha *fb* paraquat 0.6 kg/ha at 3 WAS, or atrazine 1.0 kg/ha pre-emergence *fb* topramazone 0.030 kg/ha at 30 DAS was proved location-wise effective. The tank-mix pre-emergence applications of atrazine + glyphosate (0.75+0.8 kg/ha or 1.25+0.5 kg/ha) and atrazine + paraquat (0.75+0.75 kg/ha or 1.25+0.75 kg/ha) pre-emergence was more economical in clay loam soils and sandy clay loam soils, respectively, when compared with selective herbicides alone.

Future thrusts

Successful adoption of zero till sown maize calls for development of suitable machinery for crop establishment. Understanding of the dynamics of soil physical, chemical and biological properties, which in turn, affect root growth and crop yield is essential. Understanding of the dynamics of weed shift and herbicide residues in soil also is of paramount importance.

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