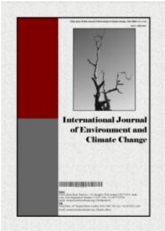

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Effect of Tillage and Weed Management Practices on Yield and Economics of Maize

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A two years study was conducted at Agricultural Research Station, Tandur, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Telangana, India during two consecutive *kharif* seasons of 2018 and 2019 to investigate the effect of tillage and weed management practices on the yield and economics of maize. The experiment was carried out in strip-plot design with tillage methods assigned to vertical plots and weed management practices allotted to horizontal plots which were replicated thrice. It was observed that there is no significant difference between tillage methods, but weed management practices significantly influenced the yield of maize. The findings revealed that conventional tillage and hand weeding twice at 20 and 40 days recorded higher cost of cultivation, gross returns and net returns, while a higher B-C ratio was observed under reduced tillage and Atrazine 50% WP at 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g *a.i.* ha^{-1}. The interaction effect between tillage and weed management practices on grain yield was found to be non-significant.

Keywords: Atrazine; economics; maize; reduced tillage; weed; tembotrione.

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1. INTRODUCTION

Maize (*Zea mays* L.) belongs to the family *Poaceae* is one of the most important grain crops in the World's agricultural economy as a staple food crop for human beings, feed for animals, and as a basic raw material for the production of starch, oil, proteins, alcoholic beverages, food sweeteners, and more recently as bio-fuel [1]. Before the beginning of the twenty-first century, India was a net importer of maize, and the productivity was not enough to meet the growing demand from poultry and other sectors. However, adoption of hybrids, particularly in non-traditional maize growing states like Karnataka and Andhra Pradesh, and to some extent in some of the traditional maize growing states like Bihar and Maharashtra, enhanced the maize yield and production in the country sharply to higher levels, which not only assured its self-sufficiency but also gave some scope on the export [2]. In India, it is cultivated in an area of 9.56 M ha with production and productivity of 28.76 MT and 3006 kg ha^{-1}, respectively [3]. Out of the total maize produced in India, about 35% is used for human consumption25% for poultry feed and cattle feed each and 15% in food processing and other industries (corn flakes, popcorn, starch, dextrose, corn syrup, corn oil, etc.) [4].

Conventional agriculture is characterized by intense tillage for weed control and an increase in crop productivity but increases soil erosion and soil degradation, which has a negative impact on the environment and natural resources. In this context, conservation agriculture (CA) with three key principles of minimum soil disturbance, crop rotations and residue retention has opened a new paradigm to increase resource use efficiency and mitigation of adverse effects of climate change by increasing carbon sequestration and reducing GHGs (Green House Gases) emissions. The major challenges perceived for low adoption of CA in rainfed regions of developing countries by the producers are: non-availability of CA machinery, competing demand for crop residues for alternative uses, crop-weed competition and weed management [5]. Hence, the benefits of CA systems in irrigated regions in general and rainfed regions in particular, may be offset by heavy weed infestation and shifts in weed communities (increase, decrease or extinction of a weed species) [6], since weeds are both agronomical and ecologically key variables in crop production. Weeds reduce maize yields by an average of 12.8% despite weed management measures and 29.2% if no weed control is used [7]. So, the maize crop must be kept free of weeds for the initial period of 30 days after crop emergence. Wider spacing coupled with increased fertilizer application and slow germination of maize favour the weed growth which results in drastic yield reduction. Repetitive tillage operations are not necessary if weeds are controlled by cultural or chemical methods. Further, various studies have shown that in many cases tillage operations as intensive as practiced are not required. Information on the influence of preparatory tillage and different weed management practices on the weed dynamics and the productivity of crops is rarely available. Therefore, a field experiment entitled “effect of tillage and weed management practices on weed dynamics, yield attributes and yield of maize in Southern Telangana Zone” is planned.

2. MATERIALS AND METHODS

A field investigation was conducted during two consecutive *kharif* seasons of 2018 and 2019 at Agricultural Research Station (ARS), Tandur which is geographically situated at an altitude of 461 m above mean sea level (MSL) (17^o 15’ N latitude and 77^o 35’ E longitude). During the growth period, a total rainfall of 374.70 mm was received in 31 rainy days during *kharif* 2018 and 675.20 mm in 49 rainy days during *kharif* 2019. The crop was grown completely under rainfed conditions. The soil was clay loam in texture having pH 7.91, EC 0.30 dSm^{-1}, organic carbon 0.34%, available N, P and K 228.60, 23.42 and 405.57 kg ha^{-1}, respectively. The experiment was laid out in a strip plot design with three replications. The treatments comprised of two tillage methods *viz.*, conventional tillage (T_1) and reduced tillage (T_2) assigned to vertical plots (378 m^2) and seven weed management practices *viz.*, Weedy check (W_1), Weed free (W_2), Intercropping with cowpea (W_3), Atrazine 50% WP @ 0.5 kg *a.i.* ha^{-1} + Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (early PoE) *fb* HW at 40 DAS (W_4), Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (PoE) (W_5), Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* paraquat 24% SL @ 1.0 kg *a.i.* ha^{1} (PoE) (W_6) and Sorghum + Parthenium leach @ 15 L ha^{-1} each (PE) *fb* Sorghum + Parthenium leach @ 15 L ha^{-1} each (PoE) (W_7) which were allotted to the horizontal plots (54 m^2). Buffer strips of 1 m width were kept between the plots. Description of the tillage methods is furnished in Table 1.

Maize hybrid DHM-117 was hand-dibbled on a flat bed at a spacing of 60 × 20 cm and grown with all general cultivation practices except for tillage and weed management practices. The required quantities of herbicides and leaches were administered according to treatment *i.e* as pre-emergence at one day after sowing of the seeds, as early-post emergence at 15 DAS and as post-emergence at 25 DAS of the crop. Spraying was done using a knapsack sprayer fitted with a flat fan nozzle, and paraquat was applied with a hood. Hand weeding was done in weed free treatment with the help of hand hoe at 20 and 40 DAS. In the intercropping system treatment, two rows of cowpea (*vigna unguiculata* L.) variety TPTC-29 was planted in between two rows of maize. Oven-dried powders of allelopathic plants (Sorghum and Parthenium) were soaked in water in 1:10 (w/v) for 48 hours. Finally, extracts were filtered through muslin cloth to obtain respective water extracts [8]. A uniform dose of 180 kg N, 60 kg P_2O_5 and 50 kg K_2O ha^{-1} was applied to all plots. Entire doses of phosphorus and potassium were applied as basal in the form of DAP and MOP respectively. Nitrogen in the form of urea after calculating the proportion is supplied through DAP was applied in three splits as per schedule *i.e*., 1/3rd N as basal, 1/3rd N at 30 DAS and remaining 1/3rd N at 60 DAS.

3. RESULTS AND DISCUSSION

3.1 Yield

The data pertaining to yield is placed in Table 2. The grain yield of maize was not influenced significantly by the tillage methods. However, yields were numerically higher under conventional tillage over reduced tillage. Conventional tillage had produced 8.67% (5152 kg ha^{-1}) higher grain yield than reduced tillage (4705 kg ha^{-1}). Increased grain yield in CT is due to deeper root spread and more root activity. Better tillage methods reduce bulk density, weed density, weed dry matter and increase nutrient and water availability, allowing for more effective water and nutrient uptake, which resulted in increased grain output. The findings are also consistent with those of Anjum et al. [9] and Khan et al. [10]. The lower seed yield with the reduced tillage where the soil was less undisturbed could be attributed to the inferior value of plant growth and yield attributing characters. Similar results were obtained by Feng et al. [11].

Weed management practices had a significant effect on grain yield. The maximum grain yield was produced by hand weeding twice at 20 and 40 DAS (6625 kg ha^{-1}) which was at par with Atrazine 50% WP @ 0.5 kg *a.i.* ha^{-1} + Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (early PoE) *fb* HW at 40 DAS (6442 kg ha^{-1}) and Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (6236 kg ha^{-1}). The highest grain yield in these treatments could be due to reduced competition between the crop and weeds for available resources throughout the crop growing period, allowing the crop to make the best use of nutrients, moisture, light and space thus enhancing the crop's vegetative and reproductive potential, which was reflected in higher grain yield. The minimum grain yield was generated by a weedy check (2578 kg ha^{-1}). This was due to increased competition for growth resources between the crop and weeds, as evidenced by lower crop stature, yield attributes, and eventually maize grain yield. The results corroborate the findings of Parameswari et al. [12] and Prithwiraj et al. [13].

The yield reduction under intercropping can be attributed to competition for moisture, nutrients and solar radiation associated with intercropping mixtures [14]. The reduction of cowpea yield under intercropping with maize could be attributed to the interspecific competition between the intercrop components for water, light, air and nutrients, as well as the aggressive effects of maize (C_4 species) on cowpea, (C_3 species) [15]. The shading of the cowpea by the taller maize plants may also have contributed to the decrease in intercropped cowpea yields [14, 16]. The low competitive capacity of legumes compared to the cereals has been ascribed to its short root system, shallow root distribution, resulting in the low competitive ability for mineral nitrogen [17].

3.2 Economics

The data regarding the economics of maize was furnished in Table 3.

3.3 Cost of Cultivation (ha^{-1})

The highest cost of cultivation was recorded with conventional tillage (30765 □ ha^{-1}). As expected the cost of cultivation with reduced-tillage (27795 □ ha^{-1}) was the lowest. Reduced tillage resulted in a lower cost of cultivation, due to the less use of machinery, labour and less fuel cost. The highest cost incurred towards the cultivation of maize crop in conventional tillage was due to more number of tillage operations, fuel consumption and labour requirement [18,19, 20].

The cost involvement was minimum with W_1 treatment *i.e*., Weedy check (24632 ha^{-1}). Highest cost of cultivation in maize was recorded with W_4 [Atrazine 50% WP @ 0.5 kg *a.i.* ha^{-1} + Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (Early PoE) *fb* H.W at 40 DAS] (35450 ha^{-1}) which was followed by W_2 [Weed free] (34632 ha^{-1}) and W_5 [Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (PoE)] (30817 ha^{-1}). In the weed-free treatment, hand weeding was done during cropping season to keep the field free of weeds. This incurred a higher cost of cultivation compared to that in tank mix and sequential application of herbicides due to higher labour cost. The highest cost of cultivation in W_4, W_2 and W_5 treatments was due to the cost involved in hand weeding and application of both pre and post-emergence herbicides. Similar findings were reported by Arunkumar et al. [21] and Prithwiraj et al. [13].

3.4 Gross Returns (ha^{-1})

The highest gross returns of maize crop in conventional tillage (90966 ha^{-1}) were due to higher grain yields than reduced tillage (83123 ha^{-1}). Similar findings were reported by Anjum et al. [9], Kihara et al. [22] and Meena et al. [20].

The highest gross returns in maize were recorded with W_2 [Weed free] (116722 ha^{-1}) which was followed by W_4 [Atrazine 50% WP @ 0.5 kg *a.i.* ha^{-1} + Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (Early PoE) *fb* H.W at 40 DAS] (113524 ha^{-1}) and W_5 [Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (PoE)] (109932 ha^{-1}). Lower gross returns were observed under W_1 [Weedy check] (45952 ha^{-1}). Efficient weed control through hand weeding and the application of both pre and post-emergence herbicides in W_4, W_2, and W_5 reduced crop-weed competition resulted in increased utilization of nutrients, moisture, light and space and reduced pest-disease incidence which helped in increasing grain yield and higher gross returns. Similar findings were reported by Ahmed and Arunkumar et al. [21], Prithwiraj et al. [13] and Sanodiya et al. [23].

3.5 Net Returns (ha^{-1})

The highest net returns were recorded with conventional tillage (60201 ha^{-1}) when compared with reduced tillage (55328 ha^{-1}). This was mainly due to higher crop yields and gross returns which resulted in higher net returns. Although the cost of cultivation of maize in RT was lowest but the advantage of reduced cost of cultivation was marked by higher weed density and weed dry matter under this treatment, restricting poor resource use by the crop, owing to tough crop weed competition. This resulted in low crop yield thus reduced net returns. Similar results were reported by Anjum et al. [9], Meena et al. [20] and Rathika and Ramesh [24].

Higher net returns in maize were recorded with W_2 [Weed free] (82089 ha^{-1}) which was followed by W_5 [Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (PoE)] (79115 ha^{-1}) and W_4 [Atrazine 50% WP @ 0.5 kg *a.i.* ha^{-1} + Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (Early PoE) *fb* H.W at 40 DAS] (78074 ha^{-1}). Lower net returns were observed under W_1 [Weedy check] (21320 ha^{-1}). The higher net returns in all of the weed management treatments as compared to weedy check treatment were due to higher grain yield provided by reduced weed density and weed dry matter as a result of effective weed control. Another possible reason that can be ascertained by these findings is that this could have happened due to the fact that all treatments associated with weed control measures were more remunerative than weedy check with regard to net monetary returns. The findings confirm the results of Sonali et al. [25].

Table 1. Tillage practices adopted in maize crop

Tillage	No. of tillage operations	Tillage implement	Timing of tillage operations
Conventional tillage (CT)	2	Cultivator	▪ Summer season ▪ Before sowing
Reduced tillage (RT)	1 1 1	Rotavator Cultivator Blade harrow	Before sowing Before sowing

Table 2. Yield (kg ha^{-1}) and Harvest Index (%) of maize as influenced by tillage and weed management practices (Pooled data of 2 years)

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
Vertical Plots : Tillage Practices (T)			
T_1 - Conventional tillage (CT)	5152	7242	40.94
T_2 - Reduced tillage (RT)	4705	6712	40.30
SE(m)±	85.71	111.57	0.84
CD (p=0.05)	NS	NS	NS
CV (%)	7.97	7.33	9.53
Horizontal Plots: Weed Management (W)			
W_1 - Weedy check	2578	5415	32.74
W_2 - Weed free (HW at 20 and 40 DAS)	6625	8221	44.82
W_3 - Intercropping with Cowpea	4425 (MEY)	6437	40.90
W_4 - Atrazine 50% WP @ 0.5 kg *a.i.* ha^{-1} + Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (Early PoE) *fb* H.W at 40 DAS	6442	8105	44.46
W_5 - Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g a.i. ha^{-1} (PoE)	6236	8025	43.87
W_6 - Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Paraquat 24% SL @ 1.0 kg *a.i.* ha^{-1} (PoE)	5143	7022	42.50
W_7 - Sorghum + Parthenium leach @ 15 L ha^{-1} (PE) *fb* Sorghum + Parthenium leach @ 15 L ha^{-1} (PoE)	3050	5614	35.03
SE(m)±	152.20	201.03	1.29
CD (p=0.05)	468.99	619.43	3.98
CV (%)	7.56	7.06	7.80
Interaction			
T×W			
SE(m)±	207.00	285.30	1.78
CD (p=0.05)	NS	NS	NS
W×T			
SE(m)±	209.46	283.96	1.76
CD (p=0.05)	645	NS	NS

MEY: Maize Equivalent Yield

Table 3. Economics of maize as influenced by tillage and weed management practices (Pooled data of 2 years)

Treatments	Cost of cultivation (□ ha^{-1})	Gross returns (□ ha^{-1})	Net returns (□ ha^{-1})	B-C ratio
Vertical Plots : Tillage Practices (T)				
T_1 - Conventional tillage (CT)	30765	90966	60201	2.90
T_2 - Reduced tillage (RT)	27795	83123	55328	2.93
Horizontal Plots : Weed Management (W)				
W_1 - Weedy check	24632	45952	21320	1.86
W_2 - Weed free (HW at 20 and 40 DAS)	34632	116722	82089	3.37
W_3 - Intercropping with Cowpea	26432	78194	51762	2.96
W_4 - Atrazine 50% WP @ 0.5 kg *a.i.* ha^{-1} + Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (Early PoE) *fb* H.W at 40 DAS	35450	113524	78074	3.20
W_5 - Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g a.i. ha^{-1} (PoE)	30817	109932	79115	3.57
W_6 - Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Paraquat 24% SL @ 1.0 kg *a.i.* ha^{-1} (PoE)	27166	90767	63601	3.34
W_7 - Sorghum + Parthenium leach @ 15 L ha^{-1} (PE) *fb* Sorghum + Parthenium leach @ 15 L ha^{-1} (PoE)	25832	54222	28390	2.10

3.6 B-C ratio

The highest B-C ratio was recorded with reduced tillage in maize (2.93) as compared to conventional (2.90). This was mainly due to lower expenditure on land preparation, higher yields and higher gross returns resulting in a higher benefit-cost ratio [22,26].

Higher B-C ratio in maize was recorded with W_5 [Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (PoE)] (3.57) which was followed by W_2 [Weed free] (3.37), W_6 [Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Paraquat 24% SL @ 1 kg *a.i.* ha^{-1} (PoE)] (3.34), and W_4 [Atrazine 50% WP @ 0.5 kg *a.i.* ha^{-1} + Tembotrione 42% SC @ 120 g *a.i.* ha^{-1} (Early PoE) *fb* H.W at 40 DAS] (3.20). Minimum B-C ratio was observed under W_1 [Weedy check] (1.86). Better control of weeds in terms of density and dry weight and higher yields may have increased the benefit-cost ratio in the W_5, W_2, W_6, and W_4 treatments. The findings corroborate the results of Ahmed and Susheela (2012), Arunkumar et al. [21] and Prithwiraj et al. [13].

4. CONCLUSION

Conventional tillage reduced total weed density and weed dry matter and increased the yield of maize with no significant difference between them. Conventional tillage and hand weeding twice at 20 and 40 DAS recorded higher cost of cultivation, gross returns and net returns, while a higher B-C ratio was observed under reduced tillage and Atrazine 50% WP @ 1.0 kg *a.i.* ha^{-1} (PE) *fb* Tembotrione 42% SC @ 120 g *a.i.* ha^{-1}.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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