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Efficacy of Herbicides on Nutrient Uptake of Crop, Weed and Its Impact on Soil Microflora of Irrigated Maize (*Zea mays* L.)

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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

Aim: Field experiment was conducted to study the suitable weed management methods to check the nutrient depletion by weeds, check the dynamics of microbial population and in relation to improve the biomass stover yield of maize (*Zea mays* L.).
Study Design: This experiment laid out in a randomized block design and 8 different weed management treatments with three replications.
Place and Duration of Study: Field experiment was conducted at Agricultural College and Research Institute, Madurai, Tamil Nadu Agricultural University, Tamil Nadu in *kharif* 2019.
Methodology: TNAU maize hybrid CO-6 was used for this experiment. Treatments were

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application of pre-emergence herbicide atrazine at 0.25 kg/ha or pendimethalin 1 kg/ha applied singly on 3 days after sowing and in combination with post-emergence herbicide tembotrione 120 g/ha or halosulfuron methyl 90 g/ha on 25 DAS, weed free check, unweeded check in maize crop. Weed nutrient depletion and microbial population was analysed in laboratory.

Results: The application of pre-emergence atrazine 0.25 kg/ha followed by post-emergence tembotrione 120 g/ha effective in controlling of grasses and BLW and enhance the nutrient uptake of maize. The stover maize yield increased with application of herbicides and sequential application of herbicides achieved 88% improved stover yield over unweeded check. Sequential application of herbicides initially reduce the population of soil microflora but the population gradually build up in all the herbicide applied plots at 60 days after application.

Conclusion: Based on the results of the experiment, it was concluded that pre-emergence atrazine 0.25 kg/ha followed by post emergence tembotrione 120 g/ha effective in controlling of weeds and enhance the nutrient uptake and stover yield of maize without much adverse impact on soil microbial population.

Keywords: Herbicides; nutrient uptake; crop; weed; soil microflora; maize.

1. INTRODUCTION

Maize is one of the most important staple food crop in the world. It has the highest genetic yield potential. However, maize grain and stover yield is reduced by several limiting factor. Among all, weed infestation and improper weed management poses severe yield reduction. The yield losses by weeds can be extend upto 18 to 65% [1]. Maize was grown in wider spacing, provide favorable condition for early growth of weeds. Weeds are the most destructive crop pest, which interfere the crop growth by competing the growth limiting factors such as light, water and nutrient. Maize and weeds lifecycle overlap and weeds extract more amount of resources from soil and reduce the availability of resources to crop.

Mineral nutrition's is an important growth factor plays a key role in successful maize production. Plant nutrients present in the soil are abundantly extracted by weeds for own biomass production, it leads to reduce the quantum of nutrients from the native pool resulted in reduction of growth and yield of crop. The degree of weed competition and nutrients removal is determined by the intensity and duration of weed infestation. Competition for nutrients between crop and weeds result in reduced the nutrient availability to crop, impact in decline the maize yield. Crop yield loss by weeds in proportional to the amount of nutrients depleted by weeds. Nazreen et al. [2] reported, in unweeded condition weeds are able to remove the highest amount of nutrients compared to plots treated with weed management practices.

Maize require unhindered nutrients during critical period assumes greater importance for realizing higher yield. Hence minimal weed interference should maintain for higher maize yield. Manual weeding is one of the effective methods for weed control during the critical period. But timely weed management has become difficult due to unavailability of man force and escalating wages during peak period [3]. Hence, herbicides are considered as alternative and effective weed control measure to implement in larger area than hand weeding. Use of pre emergence herbicides such as pendimethalin and atrazine has been found effective in early stages of weeds, but second flesh of weeds was controlled by post emergence herbicides. Moreover continuous application of voluminous herbicides may affect the soil environment. For sustained crop production applied herbicides are have fair impact to the health of soil. Microorganism are the prior biological indicator for the health of soil. In view of this facts the investigation deals with the impact of herbicides to check the nutrient removal by weeds, in relation to crop nutrient uptake and study the herbicide impacts on population of soil microflora.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil Analysis

The field experiment was designed at Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University - Madurai. The experiment was conducted during South West monsoon (July) season of 2019 to study the effect of sequential application of herbicides on nutrient removal by weeds and their impact on soil microflora. The experimental field was geographically situated between 9^0.54' N latitude and 78^0.54' E longitude with an altitude of 147 meters above the mean sea level, which will comes under the southern agro climatic zone of Tamil Nadu, India. The soil was sandy clay loam in nature with pH of 7.65. The initial soil contain medium amount of nitrogen and phosphorus content (272 and 16 kg/ha respectively) and high amount of potassium (353 kg/ha). The organic carbon content of the soil was 0.48%.

2.2 Agronomic Practices

The test crop is maize [*Zea mays* L.]. *TNAU maize hybrid Co-6* was used as a test variety for the experimentation. Healthy and viable maize seed were dibbled on the side of the ridges by adopting a spacing of 60 x 25 cm. The recommended dose of fertilizers for irrigated condition (250:75:75 kg NPK/ha) were applied in the form of urea, single super phosphate and muriate of potash. The entire dose of phosphorus and potassium and 25% nitrogen were applied as basal. Remaining 50% N and 25% N was top dressed at 25 and 45 days after sowing. Irrigation was scheduled on need basis at an interval of 7 to 10 days.

2.3 Experiment Details

The experiment was laid out in Randomized Block design with three replications. The gross plot size of the experimental site was 24 m^2 (6 m x 4 m). The treatments comprised of T_1-Atrazine 50 WP (Foost, Bayer Crop Science, India) at 0.25 kg/ha as pre emergence at 3 DAS followed by one hand weeding at 25 DAS, T_2-Pendimethalin 38.7 CS (Dost Super, UPL Limited, India)at 1 kg/ha as pre emergence at 3 DAS followed by one hand weeding at 25 DAS, T_3-Atrazine 50 WP at 0.25 kg/ha as pre emergence at 3 DAS followed by tembotrione 34.4 SC (Laudis, Bayer Crop Science, India) at 120 g/ha as post emergence at 25 DAS, T_4-Pendimethalin 38.7 CS at 1 kg/ha as pre emergence at 3 DAS followed by tembotrione 34.4 SC at 120 g/ha as post emergence at 25 DAS, T_5-Atrazine 50 WP at 0.25 kg/ ha as pre emergence at 3 DAS followed by halosulfuron methyl 75 WG (Sempra, Dhanuka, India) at 90 g/ha as post emergence at 25 DAS, T_6-Pendimethalin 38.7 CS at 1 kg/ha as pre emergence at 3 DAS followed by halosulfuron methyl 75 WG at 90 g/ ha as post emergence at 25 DAS, T_7-weed free check (weekly interval weeding) and T_8-unweeded check. Weed management practices were imposed as per treatment schedule. High volume sprayer with flat fan nozzle with the spray volume of 500 l/ha was used to apply the herbicides. Herbicide requirement was calculated based on plot size.

2.4 Plant and Weed Analysis

The plant samples of maize and weeds taken at 40 days after sowing were ground into fine powder in willey mill and used for chemical analysis of nutrient content. The total N, P and K content in crops and weeds (at 40 DAS) was determined by different methods given in Table 1. The uptake of N, P and K by crops calculated by multiplying with yield of crops while uptake of nutrients by weeds was calculated by multiplying with the dry matter accumulation of weeds at 40 DAS by the respective percentage composition of N, P and K. The triple acid used for plant P and K contained HNO_3, H_2SO_4 and $HClO_4$.

2.5 Microbial Analysis

Population dynamics of different types of microorganisms in soil samples (weekly interval pooled samples after herbicide application) collected from individual plots were studied upto 60 DAS. Soil samples were serially diluted up to a desired level and 100 µ ml suspension was added to 15-20 ml of the desired medium separately and plated in three petri plates. The plates were incubated at room temperature 3 days for bacteria, 4 days for fungi and 6 days for actinomycetes and the number of colonies were counted. Media used for the estimation of population dynamics of different microbial communities is furnished in Table 1.

2.6 Statistical Analysis

The data on different parameters were analyzed statistically by adopting Fisher's method of ANOVA suggested by Gomez and Gomez [6]. The data on microbial population were subjected to log 10 (X) transformation before analysis. The collected data was compared by LSD using SPSS.

Table 1. Methods and media used for plant and soil analysis

Plant and weed analysis	
	Method
Nitrogen	Microkjeldhal [4]
Phosphorous	Triple acid digestion and Calorimetry [5]
Potassium	Flame photometer [5]
Microbial analysis	
	Media
Bacteria	Nutrient Agar
Fungi	Rose Begal Agar
Actinomycetes	Kenknights Agar

3. RESULTS AND DISCUSSION

3.1 Nutrient Removal by Weeds

The predominant weed flora observed in the experimental field was *Dactyloctenium aegyptium* and *Echinochloa colonum* in grasses, *Cyperus esculentus and Cyperus rotundus* in sedges and *Acalypha indica, Boerhavia erecta*, *Cleome viscosa, Commelina benghalensis, Croton sparsiflorus, Eclipta alba, Phyllanthus maderaspatensis, Phyllanthus niruri and Trianthema portulacastrum* in broad leaved weeds. Nutrient demand was varied to each weeds and they have dissimilar morphological features to absorb the nutrients. The weed density and weed dry weight was given in Table 2. Data related to nutrient uptake by weeds and crop and relation with stover yield are tabulated in Table 3. Uncontrolled weed growth produced heavy biomass result in significant loss of nutrients in unweeded check. Irrespective of dominance of the weeds in the experimental field (Fig. 1), it extract more amount of nutrient from the soil pool. The *Cyperus sp.* Are the most unmanageable problematic weeds that extract high amount of nitrogen (41.33 kg/ha) and phosphorus (14.11 kg/ha) than other weeds. But potassium uptake (36.89 kg/ha) was highest in dicot weed of BLW. The results confirmed that nutrient requirement was dissimilar to each kind of weeds and monocots required more amount of nitrogen and phosphorus. Similar results are in corroborate with the findings of Deewan et al. [7]. Continuous removal of new flush of weeds at regular interval under the weed free treatment resulted in maximum elimination of weed competition as it resulted in minimum weed biomass. The weed free treatments performed better than all the herbicidal treatments in reducing the biomass of weeds resulted the minimum nutrient removal by weeds. However, controlling of *Cyperus* are very much difficult in weed free check. Hence minimum nutrient was removed by sedges. Remove the top vegetative parts of *Cyperus sp.* stimulate the aggressive new flesh within 2-3 days after manual weeding. Many of the pre and post emergence herbicides fail to control sedges. It might be due to the fact that the underground tubers act as food reserve to sedges for longer period, thus making it difficult to control. Among the sequential application of herbicides, pre emergence application of atrazine or pendimethalin followed by post emergence halosulfuron methyl at 90 g/ha treatments registered significantly lowest incidence of *Cyperus* resulted complete arrest of nutrient removal by *Cyperus sp* (Table 2). This is in accordance with findings of Kumar [8]. It was due to that halosulfuron methyl was effective translocate herbicides in killing the underground nuts [9] and it might be rapidly absorbed by foliage as well as roots of *Cyperus sp* [10]. Among the herbicide treatments, pre-emergence atrazine at 0.25 kg/ha followed by post emergence tembotrione at 120 g/ha recorded the lowest biomass of grasses and BLW throughout the crop-weed competition period resulted reduced the nutrient removal by that weeds. This might due to the control of weeds at the germination phase by the pre emergence application of atrazine and significant reduction at later stages as late germinating weeds were controlled by post emergence application of tembotrione.

3.2 Nutrient Uptake by Crop and Stover Yield

Quantity of nutrient uptake by crop is the reflection of biomass production and it is based on available nutrient in soil medium. The nutrient removal pattern by weeds severely influence the availability of nutrients to crop. Weed intensity reduced the availability of resources to the crop and thus resulting in lesser biomass of crops. Nutrients are play a key role to decide the yield of the crop. Interference of weed reduced the nutrient uptake by crop and reduce the cell division and multiplication. The crops are very hard to absorb the required nutrient from competitive nutrient pool resulted low yield in unweeded check. It might be maximum utilization of nutrients by weeds rather than crop as a result of high degree of weed competition and showed earlier water stress and nutrient deficiency over other plots. These findings were confirmative with Tollenaar et al. [11]. Weed free condition, more nutrients are available for crop and it improve the nutrient uptake and yield of crop (Table 3). This might due to minimal or no competition between crop and weed, it ultimately provided congenial atmosphere for efficient utilization of nutrients resulted higher stover yield (12793 kg/ha). Similar results are confirmed by Bahar et al. [12]. Generally weed free condition is very difficult to maintain in field level. Hence chemical weed control is vital tool for cost effective weed control in maize. Effective weed control by herbicides resulted in reduce the weed density and weed biomass, it provide a favorable condition to improve the nutrient uptake by crop. Among the sequential application of herbicides pre-emergence atrazine at 0.25 kg/ha followed by post emergence tembotrione at 120 g/ha recorded the highest amount of nutrient uptake by crop resulted high stover yield (12230 kg/ha). Effective weed control in atrazine at 0.25 kg/ha followed by post emergence tembotrione at 120 g/ha plot improve the nutrient uptake and stover yield of maize and it was on par with weed free plot. The nutrient uptake in plot atrazine at 0.25 kg/ha followed by post emergence tembotrione at 120 g/ha achieve 88% increase the yield over unweeded check (6496 kg/ha).

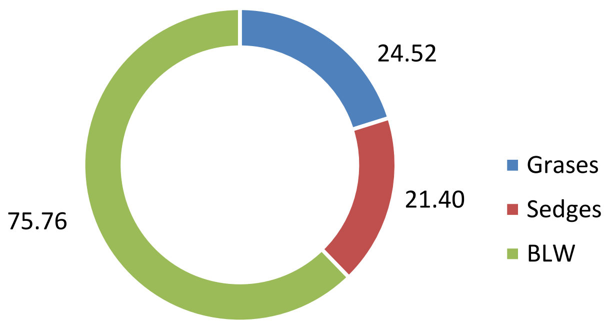


Fig. 1. Summed dominance ratio % of the experimental field

Table 2. Weed density and weed dry weight at 40 DAS

	Weed density (no/m^2)			Weed dry weight (g/m^{-2})		
Treatment	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T1	19.67 (4.48)	38.00 (6.20)	61.67 (7.88)	18.66 (4.34)	32.76 (5.76)	43.80 (6.65)
T2	23.00 (4.84)	44.00 (6.65)	64.00 (8.02)	20.01 (4.51)	35.84 (6.02)	48.89 (7.01)
T3	9.67 (3.17)	24.67 (5.01)	14.33 (3.83)	7.09 (2.75)	20.71 (4.60)	13.73 (3.77)
T4	12.67 (3.62)	27.00 (5.24)	18.33 (4.34)	11.21 (3.42)	22.01 (4.74)	14.69 (3.88)
T5	31.33 (5.62)	0.00 (0.71)	42.00 (6.51)	28.26 (5.36)	0.00 (0.71)	26.03 (5.13)
T6	36.67 (6.09)	0.33 (0.88)	42.67 (6.56)	30.28 (5.54)	0.07 (0.75)	27.89 (5.28)
T7	6.33 (2.60)	7.33 (2.76)	6.00 (2.54)	2.21 (1.65)	5.96 (2.48)	5.12 (2.36)
T8	104.33 (10.20)	90.67 (9.53)	256.00 (15.95)	84.79 (9.21)	74.27 (8.61)	310.11 (17.60)
SEd	0.35	0.37	0.60	0.38	0.32	0.53
CD (p=0.05)	0.74	0.79	1.30	0.81	0.68	1.13

Data in the parentheses are $\sqrt{x + 0.5}$ *transformed value*

Table 3. Effect of sequential application of herbicides on nutrient uptake of weeds and maize

Treatment	Grasses (kg/ ha)			Sedges (kg/ ha)			BLW (kg/ ha)			Maize (kg/ ha)			Stover yield kg/ha
	N	P	K	N	P	K	N	P	K	N	P	K	
T1	10.12	3.34	7.21	12.58	4.98	9.31	10.21	4.11	10.52	117.58	15.30	109.9633	8807
T2	10.27	3.58	7.32	13.02	5.13	9.66	10.40	4.29	10.9	109.35	14.87	102.55	8170
T3	8.02	1.94	4.19	7.85	3.85	5.39	5.44	1.52	6.23	175.27	20.49	157.2767	12230
T4	8.23	2.37	4.70	8.31	4.03	5.64	6.33	1.74	6.80	164.70	19.93	149.3367	11751
T5	12.24	4.26	5.81	0.00	0.00	0.00	7.65	2.84	8.51	146.04	18.21	136.45	10353
T6	12.43	4.54	5.94	0.00	0.00	0.00	8.56	3.05	8.79	139.92	17.41	128.39	10025
T7	2.46	0.65	2.05	3.24	2.18	3.16	1.14	0.86	3.76	191.40	22.27	177.57	12793
T8	40.95	9.83	30.58	41.33	14.11	32.89	35.52	12.14	36.89	87.54	9.92	73.32	6496
SEd	0.88	0.26	0.54	0.79	0.29	1.61	0.63	0.26	0.76	7.62	0.87	8.34	565
CD (p=0.05)	1.89	0.55	1.16	1.69	0.63	1.30	1.35	0.55	1.62	16.35	1.87	17.88	1211

3.3 Soil Microbial Population

Microbial population is one of the most important ecological indicator, which reflect the health of soil. Data related to soil microbial population are tabulated in Table 4,5 and 6. With regards to different weed management treatments on rhizosphere, the highest soil microbial population *viz.,* bacteria, fungi and actinomycetes were observed under unweeded check and weed free check. The representative population of fungi, bacteria, actinomycetes were presented in Fig. 2. Application of herbicides led to lysis of microbial cells and alter the quantity of microbial load [13]. Numerically lesser microbial population was recorded under all the herbicide applied plots during initial stage. However the effect of herbicides is usually short term and temporal reduction in microbial populations. Similar results was noticed by Ramesh and Nadanassababady [14]. The effect of pre emergence herbicides on microbes was not-significant. It might be the use of herbicides at recommended rates does not adversely affect the microbial populations. The results are in corroborate with the findings of Lupwayi *et al.* [15]. Post emergence application of herbicides significantly reduced the population of bacteria and fungi, however no significant impact on actinomycetes was observed. Similar findings were reported by Dey et al. [16]. This might be due to robust nature of actinomycetes and were capable to degrade the herbicides over bacterial and fungi. At 60 DAS, gradual buildup of microbial population in all the herbicide applied plots was registered and attained equal level to untreated plots and showed non-significant effect for all microbial populations. This might be due to the microorganisms are able to degrade herbicides and utilize them as energy sources for their own physiological processes. The result was in accordance with Hatti et al. [17].

Table 4. Effect of herbicides on soil bacteria population (10^7 cfu/g of dry soil) at different stages

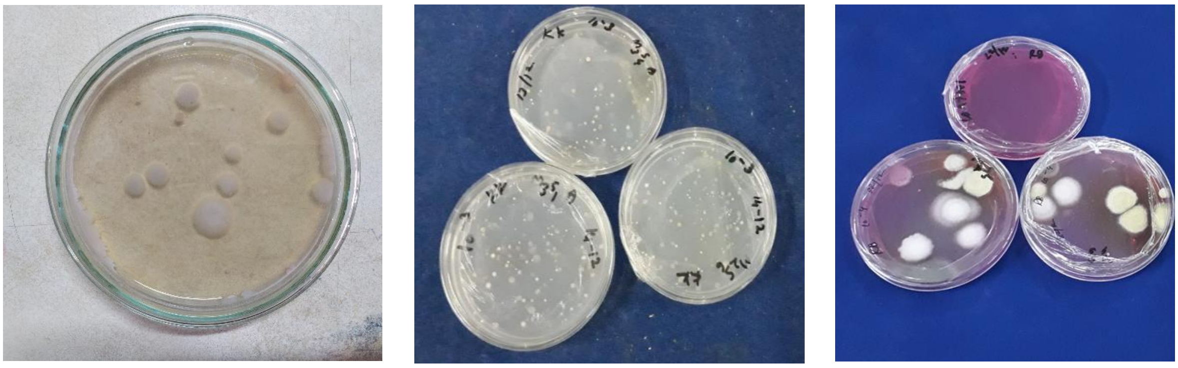
	Before PE	After PE	Before PoE	After PoE	60 DAS
T1	25.77 (8.40)	22.98 (8.34)	30.66 (8.40)	32.14 (8.51)	52.92 (8.72)
T2	28.8 (8.38)	23.81 (8.38)	32.63 (8.50)	33.45 (8.52)	3.74 (8.73)
T3	26.07 (8.36)	22.15 (8.31)	30.54 (8.41)	21.22 (8.29)	41.66 (8.59)
T4	26.43 (8.38)	24.02 (8.38)	33.96 (8.53)	22.52 (8.30)	43.01 (8.60)
T5	26.16 (8.39)	22.71 (8.33)	31.34 (8.43)	27.01 (8.43)	49.29 (8.69)
T6	25.47 (8.40)	23.33 (8.37)	32.83 (8.52)	28.72 (8.46)	50.24 (8.70)
T7	27.68 (8.37)	28.86 (8.46)	36.07 (8.56)	36.95 (8.57)	55.77 (8.75)
T8	27.65 (8.39)	28.18 (8.45)	36.62 (8.56)	37.28 (8.57)	54.82 (8.74)
SEd	0.17	0.08	0.14	0.09	0.16
CD (p=0.05)	NS	NS	NS	0.2	NS

**Data in the parentheses are log 10(X) transformed value*

Table 5. Effect of herbicides on soil fungal population (10^3 cfu/g of dry soil) at different stages

	Before PE	After PE	Before PoE	After PoE	60 DAS
T1	12.30 (4.05)	9.52 (3.93)	17.99 (4.21)	18.53 (4.27)	38.08 (4.57)
T2	12.61 (4.10)	10.49 (4.02)	20.04 (4.29)	20.46 (4.31)	38.69 (4.58)
T3	12.36 (4.09)	10.05 (3.94)	18.91 (4.20)	15.12 (4.18)	30.32 (4.46)
T4	12.29 (4.09)	10.86 (4.04)	21.07 (4.32)	15.57 (4.19)	31.45 (4.48)
T5	12.15 (4.08)	9.51 (3.95)	18.30 (4.21)	10.65 (4.01)	26.25 (4.41)
T6	12.34 (4.09)	10.71 (4.03)	20.49 (4.31)	12.1 (4.04)	27.64 (4.42)
T7	12.43 (4.09)	13.06 (4.12)	24.12 (4.38)	24.63 (4.39)	40.42 (4.61)
T8	12.58 (4.10)	13.26(4.12)	25.05 (4.40)	25.5 (4.41)	39.43 (4.60)
SEd	0.07	0.11	0.12	0.98	0.10
CD (p=0.05)	NS	NS	NS	0.2	NS

**Data in the parentheses are log 10(X) transformed value*



2a **2b** **2c**

Fig. 2a, 2b and 2c. Microbial population of bacteria, actinomycetes and fungi respectively

Table 6. Effect of herbicides on soil actinomycetes population (10^4 cfu/g of dry soil) at different stages

	Before PE	After PE	Before PoE	After PoE	60 DAS
T1	38.34 (5.54)	36.5 (5.53)	41.62 (5.62)	42.32 (5.59)	59.85 (5.77)
T2	38.22 (5.58)	37.55 (5.56)	43.85 (5.64)	44.58 (5.65)	60.56 (5.78)
T3	38.17 (5.57)	37.39 (5.52)	42.66 (5.30)	39.28 (5.42)	57.71 (5.75)
T4	38.45 (5.54)	37.97 (5.53)	44.98 (5.64)	41.87 (5.51)	58.26 (5.77)
T5	38.72 (5.59)	36.05 (5.39)	42.27 (5.52)	37.16 (5.46)	56.1 (5.74)
T6	38.7(5.55)	37.83 (5.32)	44.93 (5.29)	38.81 (5.59)	57.14 (5.73)
T7	38.63 (5.58)	40.24 (5.30)	49.2 (5.53)	49.97 (5.63)	63.23 (5.69)
T8	37.95 (5.59)	40.55 (5.53)	50.16 (5.69)	50.83 (5.67)	62.17 (5.72)
SEd	0.14	0.20	0.15	0.11	0.30
CD (p=0.05)	NS	NS	NS	NS	NS

**Data in the parentheses are log 10(X) transformed value*

4. CONCLUSION

Controlling of weeds in maize assumes great importance for realizing higher nutrient uptake and yield. Herbicides act as an alternative and effective weed management tool over manual weeding. Selected herbicides atrazine followed by tembotrione should effective in controlling of broad spectrum weeds and it check the nutrient removal by weeds and improve the nutrient uptake with high yield of maize. Moreover herbicides have adverse impact on soil health. The applied herbicide should maintain the soil equilibrium for sustained crop production. Sequential application of herbicides initially reduce the microbial population but gradually it improve the microbial load in all the herbicide applied plots. Hence application of pre-emergence atrazine 0.25 kg/ha followed by post emergence tembotrione 120 g/ha effective in controlling of weeds and enhance the nutrient uptake and stover yield of maize without much adverse impact on soil microbial population.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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