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WEED DYNAMICS AND YIELD OF RABI MAIZE (*Zea mays* L.) AS INFLUENCED BY WEED MANAGEMENT PRACTICES

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KEYWORDS

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Herbicide

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Weed density

Grain yield

ABSTRACT

A field experiment was conducted during the rabi season of 2015-16 and 2016-17 at Regional Research Sub-station, Raghunathpur, Bidhan Chandra Krishi Viswavidyalaya, Purulia, West Bengal to evaluate the post emergence herbicides application for effective weed control and influence on crop yield in maize. The treatments were arranged in a Randomized Block Design with four replications. Results of this study revealed that hand weeding recorded superiority over remaining treatments with respect to reduced weed density and increased weed control efficiency. But, it required lot of man force which was not economic to the farmer's point of view. Among the herbicidal treatments 2, 4 D Ethyl Ester 38% EC @ 1.0 kg ha^{-1} was proved to be better in controlling weeds, increasing crop yield and microbial population in the rhizosphere. 2,4 D Ethyl Ester 38% EC @ 1.0 kg ha^{-1} was recommended as a post-emergence herbicide in *rabi* maize for effective and eco-friendlycontrol of weeds and getting higher grain yield.

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1 Introduction

Maize (Zea mays L.) is the world's widely grown highland cereal and primary staple food crop in many developing countries (Ram et al., 2017). It is considered as the third most important food crop among the cereals in India and contributes to the nearly 9% of the national food basket (Jeet et al., 2017). It is also known as the queen of cereals. It is a productive food plant and has highest potential for carbohydrate per unit area per day (Aldrich et al., 1975). Maize is an important crop for food, feed and fodder for livestock, raw materials for industries and nutritional security for the many sectors in the country (Kumar et al., 2016). Strong market demand and resilience to the climate changes have increased area and production of maize in the country over the past decade (Kumar et al., 2015). It is known as miracle crop as it was used as human food and animal feed. It has cosmopolitan application in wide range of fields. In India, it occupies 8.69 m ha of the area with a production of 21.81 mt and 2509 kg ha^{-1} productivity in 2015-16 (Anonymous, 2016a). It occupies 0.16 m ha of the area with a production of 0.72 m t and 4615 kg ha^{-1} productivity in West Bengal during 2015-16 (Anonymous, 2016b). Now a days *rabi* maize (4414 kg ha^{-1}) getting more importance in farmer community as it has higher productivity than *Kharif* maize (2249 kg ha^{-1}). There are so many factors like weeds, pest and diseases affect the maize yield. One of the major problems in the area is posed by the weeds, which have shown to reduce the yields from 25 - 50% (Riaz et al., 2007). Patel et al. (2006) reported that weeds accounts for 28-100% yield loss in *kharif* maize. A broad spectrum of grasses andbroad-leaved weeds infests maize fields *viz.*, Cyperus sp., Amaranthus, Euphorbia, Trianthema, Cynodon and Dactyloctenium. These weeds can cause substantial yield reduction if not satisfactorily controlled. Weed management techniques like manual and herbicidal methods are found to be effective in controlling different groups of weeds in cropped fields (Subbulakshmi et al., 2009). Due to high cost and non-availability of labour at proper time, manual weeding was difficult during some times (Singh et al., 2013). Herbicides are major integral part in weed management practices which resulted in high yields (Baghestani et al., 2005). Herbicides are truely essential to a good yield of maize crop by suppressing different types of weeds. Chemical control is cheaper, faster, and gives better control of weeds over manual weeding. Keeping all these in view, the present study was carried out to determine how well selected post emergence herbicides worked when applied at normal use rates for weed control instead of Atrazine towards environmental sustainability and increased crop yield in maize.

2 Materials and methods

2.1 Experimental site

The experiment was conducted at Regional Research Sub-station, Raghunathpur, Bidhan Chandra Krishi Viswavidyalaya, Purulia, West Bengal in two consecutive years of 2015-16 and 2016-17. The study area belongs to humid and tropical climate characterised by a wet monsoon season (June to September) and a dry post monsoon season. The experimental site was situated at 23.55°N latitude and 86.67°E longitude with the altitude of 155 meters above the mean sea level (MSL). The soil characteristics were given in Table1.

Table 1.Basic physical,chemical and microbiological properties of the soil in the study area

Properties	Concentration	Used Methodology
Sand (%)	56.2	Piper, 1966
Silt (%)	20.3	
Clay (%)	23.5	
pH	5.51	Jackson,1967
EC (dsm^{-1})	0.14	
Organic carbon (%)	0.57	
Total N (%)	0.045	
Available P_2O_5	21.75	
Available K_2O	216.35	
Total bacteria (CFU x 10^6 $g^{-1}$of soil)	72.67	Thornton, 1922
Fungi (CFU x 10^4 g^{-1} of soil)	7.35	Martin, 1950
Actinomycetes (CFU x 10^5 $g^{-1}$of soil)	97.62	Jensen, 1930

2.2 Experimental design and treatments:

The experiment was laid out in Randomized Block Design. There were 6 treatment combinations with four replications. The treatments are comprising of 2,4 D Ethyl Ester 38% EC @ 0.9kg ha^{-1}, 2,4 D Ethyl Ester 38% EC @ 1.0 kg ha^{-1}, 2,4 D Ethyl Ester 38% EC @ 1.1 kg ha^{-1}, Diuron 80% WP@ 1.0 kg ha^{-1}, hand weeding at 20 and 40 DAS and Control. The individual plot size was 5m × 4m.

2.3 Crop management

The maize variety Disha 3502 was sown on 03-11-2015 and 06-11-2016 and harvested on 20-02-2016 and 24-02-2016 respectively taking a total duration of 107 and 108 days. The seed rate was 20 kg ha^{-1} and the row to row spacing was 45cm and plant to plant spacing was 15cm. The recommended fertiliser dose of 120:60:60 kg N, P_2O_5 and K_2O ha^{-1} was used for the crop. 50%

N along with a full dose of P_2O_5 and K_2O were applied as basal at the time of final land preparation and the rest amount of nitrogen was applied at 30 days after sowing (DAS).The herbicide 2, 4 D Ethyl Ester 38% EC was sprayed as post-emergence treatments (*i.e.* 20 DAS) and Diuron was sprayed as pre-emergence treatments (*i.e.* 2 DAS) using a water volume of 500 litres ha^{-1} with knapsack sprayer fitted with flat fan deflector nozzle.

2.4 Plant and weed sampling

The population of different types of weeds (Grasses, Broadleaf & sedge) and were recorded at 30, 45 and 60 DAA (Days after herbicide Application). A quadrate with a dimension of 1 m × 1 m was placed randomly at three places in each plot and the weeds from that area were counted and expressed as number per square meter. Weeds belonging to three categories obtained in the population at 30, 45 & 60 DAA were labelled properly. The labelled samples were sun dried for 24 hours and then oven dried at 70°C for 72 hours. The dry weight of weeds was then taken and recorded separately. For measuring the grain yield of maize, the entire produce from the net plot area (from demarcated portion, leaving the border area) was harvested and weighed after proper drying under the sun. Grain yield from that area was converted to yield $unit^{-1}$ area (kg ha^{-1}). Weed control efficiency is expressed as the percentage of control of weeds over unweeded control. It denotes the efficiency of the applied herbicide for comparison purpose. WCE of different treatments was computed on the basis of weed dry weight by using the following formula,

$$\mathrm{WCE} = \frac{\mathrm{DWC} - \mathrm{DWT}}{\mathrm{DWC}} \times 100$$

Where,

DWC = Dry weight of weeds in untreated control plot

DWT = Dry weight of weeds in treated plot

2.5 Soil sampling

After the harvest of maize crop, soil samples were collected from three different places in each plot at a depth of 30 cm and microbial population was counted as per the standard procedures.

2.6 Statistical analysis

Data were analysed using analysis of variance (ANOVA) following randomised block design (Gomez & Gomez, 1984). Differences were considered significant at 5% level of probability.

3 Results

The important weed flora observed in the experimental plot were *Trianthema monogyna, Portulaca oleracea, Euphorbia hirta, Physalis minima, Digera arvensis, Cyperus rotundus, Cyperus iria, Echinochloa colona, Digitaria sanguinalis, Eleusine indica, Brachiaria mutica, Amaranthus viridis, Alternanthera philoxeroides, Chenopodium album, Fumaria parviflora, Boerhaavia diffusa, Phyllanthus niruri and Eclipta alba.*

3.1 Weed density and dry weight

Weeds type and severity of weed infestation in field crops are considered the precursor of yield loss in a crop. Therefore, timely control of weeds is very necessary for realizing an optimum yield of any crop. The pooled data of two years pertaining to weed density and dry weight were given in table 2, 3, 4, 5, 6 and 7. Weed count and dry weight was significantly reduced in all treatments except weedy at check at 30, 45 and 60DAA. Lowest weed density and dry weight were recorded by 2,4 D Ethyl Ester 38% EC @ 1.1 kg ha^{-1} followed by 2,4 D Ethyl Ester 38% EC @

Table 2 Weed density (m^{-2}) at 30 DAA of herbicides

Treatments	*Trianthema monogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broadleaf weeds	*Cyperus*sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	4.56 (2.25)*	3.78 (2.07)	2.56 (1.75)	3.00 (1.87)	7.67 (2.86)	22.56 (4.80)
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	1.89 (1.55)	1.22 (1.31)	1.00 (1.22)	1.44(1.39)	5.44(2.44)	21.89 (4.73)
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	1.67 (1.47)	1.11 (1.27)	1.00 (1.22)	1.22 (1.31)	5.11 (2.37)	21.67 (4.71)
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	2.33 (1.68)	1.78 (1.51)	1.44 (1.39)	1.67 (1.47)	6.33 (2.61)	4.22 (2.17)
Weed free check - 20 and 40 DAS	1.44 (1.39)	1.11 (1.27)	0.78 (1.13)	1.00 (1.22)	4.22 (2.17)	2.67 (1.78)
Control	18.44 (4.35)	15.22 (3.96)	9.56 (3.17)	12.33 (3.58)	31.11 (5.62)	25.78 (5.13)
CD at 5 %	0.54	0.27	0.60	0.36	0.56	1.02

*Data in the parenthesis are transformed value; Square root transformed value of (X+0.5) was used for statistical analysis

Table 3 Weed density (m^{-2}) at 45DAA of herbicides

Treatments	*Trianthema monogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broadleaf weeds	*Cyperus*sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	5.44 (2.44)	4.33 (2.20)	3.11(1.90)	4.89 (2.32)	9.44 (3.15)	25.67 (5.12)
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	2.67 (1.78)	2.11 (1.62)	1.56 (1.44)	2.22 (1.65)	6.44 (2.63)	25.11 (5.06)
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	2.44 (1.71)	2.11 (1.62)	1.44 (1.39)	2.11 (1.62)	6.11 (2.57)	25.00 (5.05)
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	3.11 (1.90)	2.33 (1.68)	1.78 (1.51)	2.78 (1.81)	7.89 (2.90)	5.44 (2.44)
Weed free check - 20 and 40 DAS	2.33 (1.68)	1.89 (1.55)	1.33 (1.35)	2.00 (1.58)	5.67 (2.48)	3.44 (1.98)
Control	22.78 (4.82)	17.89 (4.29)	12.56 (3.61)	19.56 (4.48)	37.56 (6.17)	28.78(5.41)
CD at 5 %	0.60	0.36	0.41	0.54	0.77	1.39

*Data in the parenthesis are transformed value; Square root transformed value of (X+0.5) was used for statistical analysis

Table 4 Weed density (m^{-2}) at 60 DAA of herbicides

Treatments	*Trianthema monogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broadleaf weeds	*Cyperus*sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	8.56 (3.01)	7.33 (2.80)	6.22 (2.59)	6.67 (2.68)	13.33 (3.72)	27.00 (5.24)
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	3.67 (2.04)	3.11 (1.90)	2.44 (1.71)	2.56 (1.75)	8.56 (3.01)	26.56 (5.20)
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	3.56 (2.01)	3.00 (1.87)	2.22 (1.65)	2.33 (1.68)	8.22 (2.95)	26.33 (5.18)
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	4.33 (2.20)	3.44 (1.98)	2.78 (1.81)	3.00 (1.87)	10.44 (3.31)	8.22 (2.95)
Weed free check - 20 and 40 DAS	3.22 (1.93)	2.78 (1.81)	2.00 (1.58)	2.33 (1.68)	7.89 (2.90)	6.11 (2.57)
Control	26.67 (5.21)	22.33 (4.78)	18.44 (4.35)	19.89 (4.52)	39.67 (6.34)	30.22 (5.54)
CD at 5 %	0.68	0.43	0.49	0.56	0.86	1.44

*Data in the parenthesis are transformed value; Square root transformed value of (X+0.5) was used for statistical analysis

Table 5 Weed dry weight (g m^{-2}) at 30 DAA of herbicides

Treatments	*Trianthema monogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broad leaf weeds	*Cyperus* sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	3.81 (2.08)	2.85 (1.83)	1.63 (1.46)	1.96 (1.57)	3.72 (2.05)	15.65 (4.02)
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	1.86 (1.54)	1.24 (1.32)	0.72 (1.10)	0.87 (1.17)	2.38 (1.70)	15.24 (3.97)
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	1.72 (1.49)	1.15 (1.28)	0.68 (1.09)	0.79 (1.14)	2.25 (1.66)	15.01 (3.94)
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	2.24 (1.66)	1.51 (1.42)	1.00 (1.22)	1.11(1.27)	2.73 (1.80)	3.31 (1.95)
Weed free check - 20 and 40 DAS	1.53 (1.42)	1.12 (1.27)	0.63 (1.06)	0.77 (1.13)	1.83 (1.53)	2.08 (1.61)
Control	15.67 (4.02)	10.96 (3.39)	6.60 (2.66)	7.77 (2.88)	13.38 (3.73)	19.08 (4.42)
CD at 5 %	0.50	0.29	0.32	0.36	0.48	1.10

*Data in the parenthesis are transformed value; Square root transformed value of (X+0.5) was used for statistical analysis

Table 6 Weed dry weight (g m^{-2}) at 45 DAA of herbicides

Treatments	*Trianthema monogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broadleaf weeds	*Cyperus* sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	7.18 (2.77)	5.25 (2.40)	3.05 (1.88)	4.63 (2.26)	6.02 (2.55)	19.73 (4.50)
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	3.38 (1.97)	2.71 (1.79)	1.70 (1.48)	2.31 (1.68)	3.91 (2.10)	19.21 (4.44)
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	3.27 (1.94)	2.64 (1.77)	1.56 (1.44)	2.18 (1.64)	3.78 (2.07)	18.96 (4.41)
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	4.17 (2.16)	3.03 (1.88)	1.97 (1.57)	2.68 (1.78)	4.55 (2.25)	4.00 (2.12)
Weed free check - 20 and 40 DAS	3.06 (1.89)	2.43 (1.71)	1.41 (1.38)	2.07 (1.60)	3.57 (2.02)	3.08 (1.89)
Control	27.11 (5.25)	19.50 (4.47)	11.93 (3.53)	17.02 (4.19)	21.03 (4.64)	23.60 (4.91)
CD at 5 %	0.66	0.39	0.42	0.53	0.60	1.23

*Data in the parenthesis are transformed value; Square root transformed value of (X+0.5) was used for statistical analysis

Table 7 Weed dry weight (g m^{-2}) at 60DAA of herbicides

Treatments	*Trianthema monogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broadleaf weeds	*Cyperus*sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	11.86 (3.52)	8.56 (3.01)	6.21 (2.59)	7.05 (2.75)	8.83 (3.05)	29.06 (5.44)
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	5.61 (2.47)	4.67 (2.27)	3.05 (1.88)	3.92 (2.10)	6.01 (2.55)	28.34 (5.37)
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	5.53 (2.46)	4.45 (2.22)	3.00 (1.87)	3.75 (2.06)	5.89 (2.53)	28.01 (5.34)
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	6.82 (2.71)	5.14 (2.37)	3.89 (2.10)	4.58 (2.25)	6.37 (2.62)	6.49 (2.64)
Weed free check - 20 and 40 DAS	5.32 (2.41)	4.27 (2.18)	2.89 (1.84)	3.48 (1.99)	5.58 (2.47)	6.05 (2.56)
Control	36.54 (2.41)	27.02 (2.18)	19.36 (1.84)	23.07 (1.99)	25.39 (2.47)	33.85 (2.56)
CD at 5 %	0.60	0.44	0.54	0.47	0.65	1.26

*Data in the parenthesis are transformed value; Square root transformed value of (X+0.5) was used for statistical analysis

1.0 kg ha^{-1} in all the stages of sampling. Hand weeding twice at 20 and 40 DAS significantly recorded the lowest weed density and dry weight at 30, 45 and 60 DAA compared to other management practices.

3.2 Weed control efficiency

Data regarding weed control efficacy (Table 8, 9 and 10), revealed highest weed control efficiency was recorded in hand weeding twice at 20 and 40 DAS at 30, 45 and 60 DAA. Among the herbicides2,4 D Ethyl Ester 38% EC @ 1.1 kg ha^{-1} recorded highest weed control efficiency followed by 2,4 D Ethyl Ester 38% EC @ 1.0kg ha^{-1}.

3.3 Crop Yield

The pooled data of maize stover and grain yield was given in Table 11 revealed that hand weeding gives significantly higher stover (15.02 t ha^{-1}) and grain yield (4.64 t ha^{-1}) which was followed by 2,4 D Ethyl Ester 38% EC @ 1.1 kg ha^{-1} (4.49 and 14.86 t ha^{-1}) and this was atpar with 2,4 D Ethyl Ester 38% EC @ 1.0kg ha^{-1} (4.41 and 14.51 t ha^{-1}). Lowest straw (10.93 t ha^{-1}) and grain yield (3.18 t ha^{-1}) was observed in weedy check.

3.4 Microbial population

Data given in Table 12 reveals that total bacteria populationin 2,4 D Ethyl Ester 38% EC applied plots did not show any significant influence on the population of total bacteria in Rhizosphere soil at the initial stage. But at harvesting the recorded population slightly higher than the initial observation. There was the adverse effect on the population of fungi in Rhizosphere region at harvest, the data showed slightly higher than the initial population of the fungi.Like the bacteria and fungi, similar kind of trend was found in the case of Actinomycetes population. There was no significant difference among the herbicide treatments with respect

Table 8 Weed control efficiency (%) at 30 DAA of herbicides

Treatments	*Trianthema monogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broadleaf weeds	*Cyperus* sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	75.69	74.00	75.30	74.77	72.20	17.98
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	88.13	88.69	89.09	88.80	82.21	20.13
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	89.02	89.51	89.70	89.83	83.18	21.33
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	85.71	86.22	84.85	85.71	79.60	82.65
Weed free check - 20 and 40 DAS	90.24	89.78	90.45	90.09	86.32	89.10
Control	-	-	-	-	-	-

Table 9 Weed control efficiency (%) at 45 DAA of herbicides

Treatments	*Trianthemamonogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broadleaf weeds	*Cyperus*sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	73.52	73.08	74.43	72.80	71.37	16.40
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	87.53	86.10	85.75	86.43	81.41	18.60
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	87.94	86.46	86.92	87.19	82.03	19.66
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	84.62	84.46	83.49	84.25	78.36	83.05
Weed free check - 20 and 40 DAS	88.71	87.54	88.18	87.84	83.02	86.95
Control	-	-	-	-	-	-

Table 10 Weed control efficiency (%) at 60 DAA of herbicides

Treatments	*Trianthema monogyna*	*Portulaca oleracea*	*Euphorbia hirta*	Other Broadleaf weeds	*Cyperus*sp.	Total Grasses
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	67.54	68.32	67.92	69.44	65.22	14.15
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	84.65	82.72	84.25	83.01	76.33	16.28
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	84.87	83.53	84.50	83.75	76.80	17.25
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	81.34	80.98	79.91	80.15	74.91	80.83
Weed free check - 20 and 40 DAS	85.44	84.20	85.07	84.92	78.02	82.13
Control	-	-	-	-	-	-

to microbial population. Since the effect of herbicide treatments on the beneficial soil microbes may be considered as safer to the soil beneficial microbes.

4 Discussion

4.1 Weed density and dry weight

The better performance of these herbicides might be due to longer persistence effect. The reduced crop weed competition in hand wedding is due to regular removal of weeds in the initial and later stages of crop growth (Subbulakshmi et al., 2009; Hawaldar & Agasimani, 2012; Shankar et al., 2015). More over in the later stages of crop growth, the crop suppresses the weeds by shade and limited the availability of sunlight to reduce the biomass and density of weeds. Due to limited care and management, weedy check recorded significantly highest weed density and bio mass (Mathukia et al., 2014; Barad et al., 2016; Kumar et al., 2017). Selective post emergent herbicides reduced the weed dry weight

Table 11 Effect of Weed treatment on Maize Yield (t ha^{-1})

Treatments	Yield t/ha	
	Grain	Straw
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	3.63	11.82
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	4.41	14.51
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	4.49	14.86
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	4.06	13.67
Weed free check - 20 and 40 DAS	4.64	15.02
Control	3.18	10.93
CD at 5 %	0.81	1.71

Table 12 Influence of herbicides on soil microflora

Treatments	Total bacteria (CFU x 10^6 g^{-1} of soil)	Fungi (CFU x 10^4 g^{-1} of soil)	Actinomycetes (CFU x 10^5 g^{-1} of soil)
2,4 D Ethyl Ester 38% EC @ 0.9 kg a.i. ha^{-1}	75.67	8.00	103.56
2,4 D Ethyl Ester 38% EC @ 1.0 kg a.i. ha^{-1}	75.67	7.89	103.11
2,4 D Ethyl Ester 38% EC @ 1.1 kg a.i. ha^{-1}	75.33	7.89	102.89
Diuron 80% WP @ 1.0 kg a.i. ha^{-1}	75.44	7.89	103.00
Weed free check - 20 and 40 DAS	75.11	7.56	102.67
Control	72.89	7.56	99.44
C.D. (P=0.05)	NS	NS	NS

by controlling wide range of weeds in the maize crop (Amare et al., 2015; Baniasadi, 2016; Kumar et al., 2017).

4.2 Weed control efficiency

After hand weeding all herbicides are effective in reducing weed density and dry weights (Tesfay et al., 2014). Better weed control efficiency of herbicides along with weed free condition might be due to effective weed control obtained under hand weeding, application of herbicides mixture at initial and early growth stage, which resulted in the lowest weed counts and finally reduced the total dry weight of weeds at harvest (Ehsas et al., 2016).

4.3 Crop Yield

The improved growth and yield under these treatments might be due to the periodical removal of weeds by hand weeding or herbicide application as evidenced by less weed density, weed dry weight and weed control efficiency compared other weed management practices. The limited competition for light, moisture and nutrients in these treatments helps to gain higher yields than the weedy check (Mathukia et al., 2014; Dobariya et al., 2015; Shankar et al., 2015; Barad et al., 2016). A significant difference in grain and straw yields of maize was observed might be due to minimum weed seed bank and eradication of weeds providing a healthy environment for crop plant growth (Riaz et al., 2007). Totally, the results showed that application of herbicide led to a reduction of damages caused by weeds, also, it was determined that using of 2,4 D Ethyl Ester 38% EC had the highest effect on weed control in comparison to control resulted in increased straw and grain yield (Baniasadi, 2016).

4.4 Microbial population

The toxic effects of herbicides are normally most severe immediately after application. Few days after application of herbicides or at the time of harvest, the microbial population was increased, this was might be due to the reason that microorganisms initiate degradation process, and then the degraded herbicides release carbon rich substrates which in terms maximize the microbial population in the root zone (Adhikary et al., 2014). 2,4-D decomposes rapidly because of its hormonal properties. There is no direct effect of herbicides on the population of soil microflora. Herbicides act as a source of nutrition for microbes, under such condition they significantly affect microbial growth and multiplication (Milosevic & Govedarika, 2002). Hand weeding rendered a significant increase in the population of microorganisms in soil is might be due to the influence of available nutrients stimulatory to the soil micro flora (Khuntia et al., 2013).

Conclusion

According to the results of this study, hand weeding shown superiority in controlling weed density, weed dry matter and higher control efficiency and grain yield when compared to the remaining treatments. But, it requires a lot of man force which was not economic to the farmer point of view. Among the herbicidal treatments 2,4 D Ethyl Ester 38% EC @ 1.1 kg ha^{-1} shown better performance followed by 2,4 D Ethyl Ester 38% EC @ 1.0kg ha^{-1}in terms of controlling weeds and increasing crop yield and microbial population in the rhizosphere. As there is no much difference between 2,4 D Ethyl Ester 38% EC @ 1.1 kg $ha^{-1}$and 2,4 D Ethyl Ester 38% EC @ 1.0kg ha^{-1} response to yield and microbial population and controlling weeds, 2,4 D Ethyl Ester 38% EC @ 1.0kg $ha^{-1}$was recommended as a post emergent herbicide in *rabi* maize for effective controlling of weeds and getting higher grain yield.

Conflict of Interest

The author(s) declared no potential conflicts of interest with respectto the research or publication of this article.

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