Assessing the effect of weed management practices on weed flora, growth and yield of fodder maize (*Zea mays* L.)

ABSTRACT

A field experiment was conducted at Research Farm, AICRP on Forage Crops, Department of Agronomy, JNKVV, Jabalpur (Madhya Pradesh) during of the year 2019. The main objective of the experiment was to find out the effect of different weed control treatments on complex weed flora in fodder maize. Ten treatments were tested in randomized block design with three replications. Treatments consisted of pre-emergence application of atrazine 1000 g/ha, pendimethalin 750 g/ha, atrazine 750 g/ha + pendimethalin 750 g/ha and post emergence application of 2,4-D 500 g/ha, tembotrione 120 g/ha, topramezone 35 g/ha, tembotrione 120 g/ha + atrazine 250 g/ha, topramezone 35 g/ha + atrazine 250 g/ha, hand weeding twice at 20 and 40 DAS and weedy check. Weed intensity and dry matter accumulation by weeds were recorded species wise and then the effectiveness of weed management and the weed control efficiency were calculated. In maize field, the predominated weeds were *Echinochloa colona*, *Commelina communis*, and *Digitaria sanguinalis* among monocots, *Phyllanthus niruri* and *Eclipta alba* among dicots along with a respectable sum of numerous minor weeds. Experimental results indicated that hand wedding has recorded highest weed control efficiency (88.64%) followed by PoE application of topramezone 35 g/ha + atrazine 250 g/ha (74.38%) and tembotrione 120 g/ha + atrazine 250 g/ha (68.31%). All weed control treatments significantly affected the plant height, LAI, stem girth and leaf: stem ratio of crop. Among different herbicidal treatments, topramezone 35 g/ha + atrazine 250 g/ha was found significantly superior and gives highest green fodder yield (47.26 t/ha), dry fodder yield (13.64 t/ha), crude protein yield (1.51 t/ha), net monetary returns (Rs. 44824/ha) and B:C ratio (2.72). Thus, herbicide application of topramezone 35 g/ha + atrazine 250 g/ha was found more reliable to control complex weed flora of fodder maize with higher green fodder yield and net returns.

***Keywords**: Fodder maize, Green fodder yield, Herbicides, Weed control efficiency, Weed flora*

1. INTRODUCTION

"Maize (*Zea mays* L.) is known as 'Queen of Cereals' because of its high production potential and wider adaptability" [1, 2]. "The agricultural production systems in India are based upon mixed farming in which two major enterprises are crops and livestock. Livestock is the backbone of Indian agriculture and accounts for around 4.4 percent of the country's gross domestic product" [3]. "India ranks first in the milk production all over the world. Thus, production of good quality fodder and forage is of great importance for the development of livestock industry in the country" [4, 5]. "Fodder plays an important role in economizing the cost of production of livestock products especially of milk. Green fodder is the essential component of feeding high yielding milch animals to obtain optimum level of milk production" [6]. "The green fodder maize (African Tall) contains dry matter (22.2%), crude protein (7.1%), crude fiber (30.2%), in-vitro dry matter digestibility (65.0%), neutral detergent fibre (67.6%), acid detergent fibre (38.3%) and total ash (6.0%)" [7].

"Weed management is a severe issue in forage crop production and weeds play a large piece in fodder maize production. Worldwide yield losses in maize due to weeds are estimated to be around 37%" [8]. "Farmers usually give prime importance to few cultural practices and neglect other factors like weed control" [9]. "Maize crops are infested with a variety of weeds and subjected to intense weed competition, resulting in huge losses. Weeds are a major problem in rainy season crops due to favorable growth conditions, primarily wide spacing and initial slow growth, frequent rains, causing huge losses ranging from 28 to 100%" [10, 11, 12].

"In this context, the use of suitable herbicides is the only substitute to get higher productivity with lower cost involvement. However continuous use of the herbicide causes shift in weed flora and development of resistance to herbicides" [13, 14]. Herbicides are used to retain weed-free conditions, during the early stage of growth, either by cultural or mechanical means or through pre-planting, pre-emergence and post-emergence herbicide applications [15, 16]. "Atrazine, recommended as a pre-emergence herbicide, is not effective against some of the weeds. Globally, 45 weed species across the many corn growing areas shown resistance against photosystem II (PS II) inhibitor herbicides, like atrazine (Heap 2019). Pre-emergence or early post-emergence atrazine application followed by intercultivation has been shown to be quite successful in *kharif* maize. Farmers sometimes fails to apply atrazine as a pre-emergence spray due to excessive soil moisture as a result of exceptional rains. In such cases, applying a post-emergence herbicide may be a viable option. Most currently available herbicides, such as atrazine, pendimethalin, and alachlor, provide only a narrow spectrum of weed control in maize [17], and repeated use of a single herbicide leads to the evolution of herbicide resistant weed species and a shift in weed flora" [18]. So, there is a need for some alternate post-emergence herbicide which can provide broad spectrum weed control in *kharif* maize without affecting the crop growth and yield of crop. Henceforth, the current experiment was conducted to find out the suitable herbicides or herbicidal combination with appropriate dose to control complex weed flora associated with fodder maize and attained the highest yields.

2. MATERIALS AND METHODS

A field experiment was conducted at Research Farm, AICRP on Forage Crops, Department of Agronomy, JNKVV, Jabalpur (Madhya Pradesh) during *Kharif* season of the year 2019 to study the effect of different herbicides on growth and yield of fodder maize. The soil of the experimental field was neutral in reaction (pH 7.21) and medium in organic carbon (0.54%) as well as with medium available nitrogen (231.56 kg/ha), available phosphorus (16.59 kg/ha) and available potassium (313.66 kg/ha) contents with normal electrical conductivity (0.33). The experiment was laid out in a randomized complete block design (RCBD) with the following treatments viz., tembotrione 120 g *a.i*/ha at 20 DAS, topramezone 35 g *a.i*/ha at 20 DAS, pre-emergence application of atrazine 1000 g *a.i*/ha, pre-emergence application of pendimethalin 750 g *a.i* /ha, tembotrione 120 g/ha + atrazine 250 g *a.i*/ha at 20 DAS, topramezone 35 g *a.i*/ha + atrazine 250 g *a.i/*ha at 20 DAS, pre emergence application of atrazine 750 g *a.i/*ha + pendimethalin 750 g *a.i*/ha, 2,4-D 500 g *a.i*/ha at 20 DAS, hand weeding twice at 20 and 40 DAS and control. African tall variety of maize was sown with row spacing of 50 cm and seed rate of 40 kg per ha. Observations on weed density, weed dry matter, weed control efficiency, plant growth parameters, yield and economics of fodder maize were recorded. The quadrate of 0.25 square meter (0.5 m × 0.5 m) was randomly placed at four places in each plot and then the species wise and total weed count was recorded. The data thus obtained, were transformed and expressed in number per square meter. For calculating weed dry weight, the weeds were first sun dried and thereafter kept in paper bags and dried in oven at 60˚C for 48 hours and kept for drying till constant dry weight of weeds was achieved. The data recorded from the experiment on various studies were tabulated and subjected to their statistical analysis by the methods of analysis of variance as suggested by [19]. The data on weeds had considerable variation and hence subjected to square root transformation $\sqrt{x} \pm 0.5$ before analysis statistically as per methods proposed by [20].

3. RESULTS AND DISCUSSION

3.1 Weed flora

The important grassy weeds (*Echinochloa colona, Digitaria sanguinalis* and *Eleusine indica*), sedges (*Cyperus rotundus*) and broad-leaved weeds (*Commelina communis, Phyllanthus niruri* and *Eclipta alba*) were observed in association with maize in the experimental site.

3.2 Weed density and dry weight

All the weed management treatments significantly affected the grassy, sedges and broad leaved weeds at 45 DAS (**Table 1**). The data revealed that topramezone 35 g/ha + Atrazine 250 g/ha recorded the lowest density of all the grassy, sedges and broad leaved weeds significantly compared to all other herbicidal treatments and at par with tembotrione 120 g/ha + atrazine 250 g/ha. However, hand weeding was superior among all the weed control treatments and recorded the lowest density of all the weed species. At the same time, the density of all the dominant weeds was higher in weedy check due to uninterrupted growth of weeds as no weed control measures were adopted in weedy check plots [21].

Significant variation in weed dry weight was recorded due to different weed-management practices at 45 DAS (**Table 2**). The recorded data indicated that higher weed dry weight was recorded in the weedy check treatment, while the lowest weed dry weight was recorded in the hand weeding treatment. However, among herbicidal treatments, the application of pre-emergence herbicide topramezone 35 g/ha + Atrazine 250 g/ha recorded significantly minimum weed dry weight that established its superiority over other treatments, which is at par with tembotrione 120 g/ha + atrazine 250 g/ha. Because, topramezone with the combination of atrazine performed better to control grasses and braod leaved weeds, which leads to lower dry weight of weeds [22].

Table 1. Influence of different weed control treatments on density of weeds (no/m^2) at 45 DAS

Treatments	*Echinochloa colona*	*Digitaria sanguinalis*	*Eleusine indica*	*Cyperus rotundus*	*Commelina communis*	*Phyllanthus niruri*	*Eclipta alba*
Tembotrione 120 g/ha	8.34 (69.08)	4.76 (22.15)	2.85 (7.65)	4.57 (20.42)	4.94 (23.92)	4.75 (22.08)	2.99 (8.50)
Topramezone 35 g/ha	8.12 (65.50)	4.58 (20.44)	2.69 (6.77)	4.47 (19.50)	4.76 (22.17)	4.53 (20.00)	2.88 (7.83)
Atrazine 1000 g/ha	9.41 (88.17)	5.34 (28.07)	3.69 (13.11)	5.02 (24.75)	5.38 (28.50)	5.38 (28.50)	3.65 (12.83)
Pendimethalin 750 g/ha	9.68 (93.17)	5.44 (29.07)	3.96 (15.17)	5.19 (26.50)	5.74 (32.50)	5.68 (31.75)	3.75 (13.67)
Tembotrione 120 g/ha + Atrazine 250 g/ha	7.26 (52.17)	4.33 (18.27)	2.58 (6.17)	4.17 (16.92)	4.51 (19.83)	4.26 (17.67)	2.58 (6.17)

Topramezone 35 g/ha + Atrazine 250 g/ha	6.68 (44.58)	4.22 (17.33)	2.46 (5.58)	3.94 (15.00)	4.36 (18.50)	4.03 (15.75)	2.26 (4.67)
Atrazine 750 g/ha + Pendimethalin 750 g/ha	9.00 (80.58)	5.06 (25.10)	3.05 (8.83)	4.87 (23.25)	5.18 (26.33)	5.14 (26.00)	3.67 (13.00)
2,4-D 500 g/ha	8.51 (71.92)	4.90 (23.53)	2.97 (8.33)	4.83 (22.83)	5.13 (25.83)	4.97 (24.17)	3.31 (10.50)
Hand weeding	2.99 (8.50)	3.72 (13.38)	2.17 (4.25)	2.04 (3.67)	2.59 (6.25)	2.45 (5.50)	1.82 (2.83)
Weedy Check	10.17 (103.00)	5.85 (33.83)	5.00 (24.63)	5.58 (30.67)	6.05 (36.25)	5.91 (34.42)	4.64 (21.00)
SEm±	0.20	0.07	0.09	0.06	0.12	0.08	0.14
CD at 5%	0.59	0.21	0.26	0.17	0.37	0.25	0.41

Table 2. Influence of different weed control treatments on dry weight of weeds (g/m^2) at 45 DAS

Treatments	*Echinochloa colona*	*Digitaria sanguinalis*	*Eleusine indica*	*Cyperus rotundus*	*Commelina communis*	*Phyllanthus niruri*	*Eclipta alba*
Tembotrione 120 g/ha	4.59 (20.55)	4.10 (16.34)	3.58 (12.32)	3.21 (9.80)	3.87 (14.51)	3.88 (14.56)	3.52 (11.90)
Topramezone 35 g/ha	4.36 (18.47)	3.73 (13.40)	3.40 (11.07)	2.94 (8.13)	3.54 (12.02)	3.60 (12.47)	3.35 (10.74)
Atrazine 1000 g/ha	5.48 (29.53)	4.80 (22.53)	3.96 (15.17)	4.01 (15.61)	4.40 (18.92)	4.64 (20.99)	4.12 (16.45)
Pendimethalin 750 g/ha	5.55 (30.30)	5.00 (24.51)	4.17 (16.90)	4.46 (19.37)	4.66 (21.20)	4.99 (24.37)	4.30 (17.96)
Tembotrione 120 g/ha + Atrazine 250 g/ha	3.85 (14.36)	3.48 (11.61)	3.01 (8.58)	2.76 (7.10)	2.99 (8.45)	3.32 (10.54)	3.05 (8.80)
Topramezone 35 g/ha + Atrazine 250 g/ha	3.50 (11.75)	3.29 (10.34)	2.65 (6.53)	2.58 (6.13)	2.77 (7.19)	2.82 (7.43)	2.72 (6.90)
Atrazine 750 g/ha + Pendimethalin 750 g/ha	5.36 (28.29)	4.56 (20.32)	3.88 (14.52)	3.63 (12.70)	4.15 (16.76)	4.53 (20.03)	4.00 (15.51)
2,4-D 500 g/ha	5.17 (26.27)	4.34 (18.32)	3.72 (13.37)	3.45 (11.43)	3.97 (15.23)	4.11 (16.39)	3.84 (14.27)
Hand weeding	2.79 (7.31)	1.53 (1.88)	1.26 (1.10)	1.60 (2.10)	2.36 (5.18)	2.48 (5.73)	1.52 (1.81)
Weedy Check	8.49 (71.53)	5.36 (28.18)	4.39 (18.80)	5.20 (26.58)	5.52 (29.93)	5.47 (29.45)	4.77 (22.28)
SEm±	0.06	0.04	0.05	0.05	0.09	0.06	0.04
CD at 5%	0.18	0.11	0.14	0.15	0.27	0.18	0.13

3.3 Weed control efficiency (%)

The weed control efficiency (WCE) had significant inverse relationship with dry matter production by weeds. The weed control efficiency was recorded maximum with hand weeding twice (88.64%) at 45 DAS, because associated weeds produced minimum dry matter with this treatment. The dry matter accumulation by weeds correspondingly reduced in 2,4-D 500 g/ha, Atrazine 750 g/ha + Pendimethalin 750 g/ha, Pendimethalin 750 g/ha and Atrazine 1000 g/ha, therefore the weed control efficiency correspondingly increased with these treatments. Post emergence application of tembotrione 120 g/ha, topramezone 35 g/ha, tembotrione 120 g/ha + atrazine 250 g/ha and topramezone 35 g/ha + atrazine 250 g/ha had minimum dry matter production by weeds. Consequently, these treatments had greater value of weed control efficiency than other herbicides. However, highest weed control treatment was recorded under topramezone 35 g/ha + Atrazine 250 g/ha treatment (74.38%) among herbicidal treatments. [23, 24] also reported that, topramezone + atrazine proved most effective and they reduced the weed density and weed biomass significantly, which in turn increased WCE compared with weedy check.

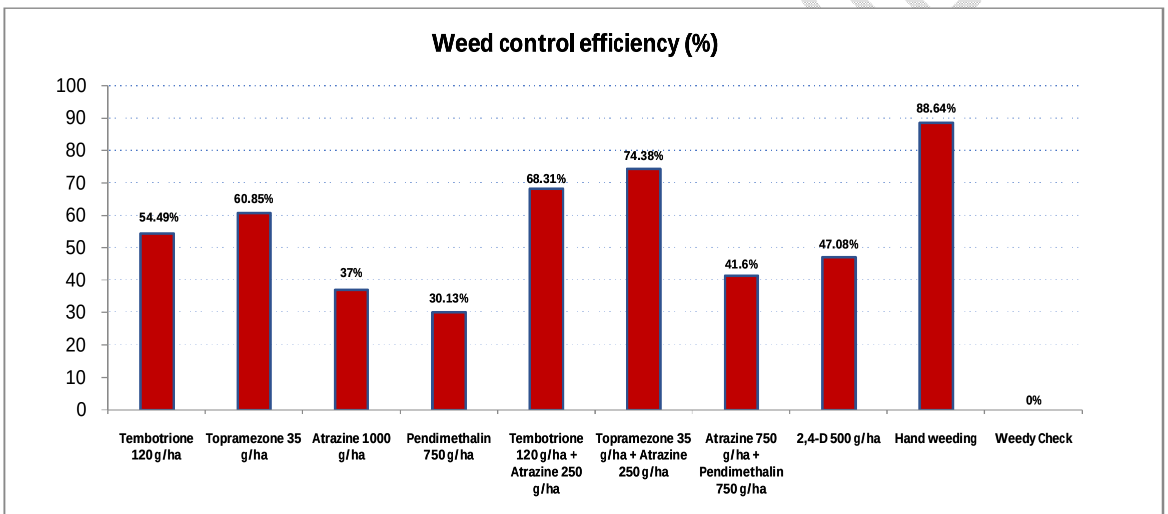

Figure 1. Influence of different weed control treatments on weed control efficiency at 45 DAS.

3.4 Growth parameters

The plant height, in general was less under all the treatment during early period of crop growth, which was increased with age of crop and was found maximum at 60 DAS (**Table 3**). Plant height was minimum (115.41 cm) under weedy check plots. However, maximum height was recorded in plots receiving twice hand weeding (21.79 cm). Among herbicidal treatments, application of topramezone 35 g/ha + atrazine 250 g/ha caused significant increase of plant height (178.97 cm) which is at par with tembotrione 120 g/ha + atrazine 250 g/ha, topramezone 35 g/ha and tembotrione 120 g/ha. "The excellent control of weeds under these treatments led to optimal utilization of growth resources therefore, these treatments have long stature plants" [25].

LAI differed significantly due to different weed control treatments at 60 DAS (**Table 3**). The LAI was maximum in weed free plot (10.24) among all weed control treatments, whereas minimum value of LAI was recorded in weedy check plots. Application of post emergence herbicides produced significantly higher LAI as compared to weedy check but, they were inferior to that of weed free plot. Among herbicidal treatments, maximum LAI was recorded in topramezone 35 g/ha + atrazine 250 g/ha (8.94). This may be because of better growth and development of foliage under weed free environment and consequently resulted in more assimilatory area per unit land area [26, 27]. Stem girth remarkably differed due to different treatments at 60 DAS crop stage (**Table 3**).

Stem girth was less (2.02 cm) in weedy check plot, due to poor control of associated weeds. Application of post emergence herbicides resulted in increased in the stem girth at all the stages. But found significantly inferior to that of topramezone 35 g/ha + atrazine 250 g/ha, (2.23 cm) as well as weed free treatment (2.27 cm) because, both the treatments provided excellent control of associated weeds, resulting in almost weed free environment throughout the critical period of crop-weed competition which, led to optimum growth and development of crop plants and ultimately resulted in more number of leaves per plant under these treatments [28].

All the weed control treatments significantly affected the leaf: stem ratio at harvest stage (**Table 3).** Significantly higher L:S ratio was observed in twice hand weeding (0.82) and was at par with topramezone 35 g/ha + atrazine 250 g/ha (0.79). Sıgnificantly lower L:S ratio among all the weed management practices was noticed in control plot (0.66) The higher L:S ratio in twice hand weeding might be due to higher vegetative growth especially leaf growth. This was due to increased availability of nutrients to the crop by reducing weed growth efficiently. Whereas, lower L:S ratio in unweeded control was mainly due to less crop growth especially leaf growth resulted from higher crop weed competition during critical stages of crop growth [29].

Table 3. Effect of weed control treatments on leaf area index, stem girth (cm) and leaf:stem ratio of maize at different growth stage

Treatments	Plant height (cm)	Leaf area index	Stem girth (cm)	Leaf: Stem
Tembotrione 120 g/ha	168.97	6.96	2.15	0.75
Topramezone 35 g/ha	170.44	7.44	2.17	0.76
Atrazine 1000 g/ha	148.07	4.04	2.07	0.69
Pendimethalin 750 g/ha	139.43	3.51	2.06	0.68
Tembotrione 120 g/ha + Atrazine 250 g/ha	178.16	7.19	2.20	0.78
Topramezone 35 g/ha + Atrazine 250 g/ha	178.97	8.94	2.23	0.79

Atrazine 750 g/ha + Pendimethalin 750 g/ha	151.91	5.30	2.09	0.71
2,4-D 500 g/ha	154.99	6.30	2.12	0.73
Hand weeding	180.58	10.24	2.27	0.82
Weedy Check	115.41	2.35	2.02	0.66
SEm±	1.43	0.27	0.01	0.004
CD at 5%	4.25	0.81	0.02	0.01

3.5 Yields

Green fodder, dry matter and crude protein yield varied significantly under different treatments (**Table 4**). Among all the treatments, the minimum green fodder, dry matter and crude protein yield were recorded under weedy check plot (34.31, 9.59, 1.04 t/ha, respectively) which was increased significantly when weed control measures were adopted. It was due to severe competition stress right from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters, green fodder and crude protein yield [30]. Maximum green fodder, dry matter and crude protein yield were recorded in twice hand weeding at 20 and 40 DAS (47.31, 13.89 and 1.52 t/ha, respectively). However, among herbicidal treatments, topramezone 35 g/ha + atrazine 250 g/ha recorded maximum green fodder, dry matter and crude protein yield (47.26, 13.64 and 1.51 t/ha, respectively). "It was due to elimination of grasses as well as broad leaved weeds from inter and intra row spaces besides better aeration due to manipulation of surface soil and thus, more space, water, light and nutrients were available for the better growth and development, which resulted into superior yield attributes and development, and consequently the highest yield" [31].

Table 4. Effect of weed control treatments on green fodder yield, dry matter yield and cruid protein yield of maize

Treatments	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Crude protein yield (t/ha)
Tembotrione 120 g/ha	40.53	12.28	1.43
Topramezone 35 g/ha	42.34	12.37	1.45
Atrazine 1000 g/ha	36.61	11.06	1.25
Pendimethalin 750 g/ha	35.47	10.76	1.12
Tembotrione 120 g/ha + Atrazine 250 g/ha	44.26	13.35	1.50
Topramezone 35 g/ha + Atrazine 250 g/ha	47.26	13.64	1.51
Atrazine 750 g/ha + Pendimethalin 750 g/ha	37.08	11.82	1.33
2,4-D 500 g/ha	37.23	12.02	1.41
Hand weeding	47.31	13.89	1.52
Weedy Check	34.31	9.59	1.04
SEm±	2.03	0.64	0.02
CD at 5%	6.34	1.91	0.06

3.6 Economics

Economic analysis of different weed control treatments in fodder maize is given in **Table 5**. The maximum GMR of Rs. 70975/ha was registered in hand weeding treatment, however maximum NMR of Rs. 44824/ha was registered in topramezone 35 g/ha + atrazine 250 g/ha followed by tembotrione 120 g/ha + atrazine 250 g/ha (Rs. 40871/ha). Similarly, maximum benefit cost ratio was found with application of topramezone 35 g/ha + atrazine 250 g/ha (2.72) followed by tembotrione 120 g/ha + atrazine 250 g/ha (2.60). It may be due to good green fodder yield obtained under these treatments because of better management of weeds. The GMR, NMR, and B: C ratio was lowest in weedy check due to more population of weeds and lesser green fodder yield in the particular treatment [32]. The differences in B: C ratio is due to the cost of herbicides and productivity of the crop.

Table 5. Economic analysis of different weed control treatments in fodder maize

Treatments	Cost of cultivation (Rs/ha)	Gross monetary returns (Rs/ha)	Net monetary returns (Rs/ha)	B:C Ratio
Tembotrione 120 g/ha	25440	60805	35365	2.39
Topramezone 35 g/ha	25990	63513	37523	2.44
Atrazine 1000 g/ha	24590	54917	30327	2.23
Pendimethalin 750 g/ha	24765	53218	28453	2.15
Tembotrione 120 g/ha + Atrazine 250 g/ha	25528	66399	40871	2.60
Topramezone 35 g/ha + Atrazine 250 g/ha	26078	70902	44824	2.72
Atrazine 750 g/ha + Pendimethalin 750 g/ha	25115	55634	30519	2.22
2,4-D 500 g/ha	24390	55855	31465	2.29
Hand weeding	34240	70975	36735	2.07
Weedy Check	24240	51469	27229	2.12

4. CONCLUSION

From the experimental results, it can be concluded that application of topramezone 35 g/ha + atrazine 250 g/ha as post emergence application at 20 DAS effectively controlled the complex weed flora of fodder maize with highest weed control efficiency and this combination of herbicide was found to be most suitable for obtaining higher green fodder yield, net return and B: C ratio. Thus, it should be recommended to the farmers that combination of topramezone 35 g/ha + atrazine 250 g/ha can be used instead of any single herbicide to effectively controls the severe infested weeds in the fodder maize with higher green fodder yield.

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