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Integrated weed management in *rabi* popcorn (*Zea mays* var. *everta*)

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ABSTRACT

The field experiment conducted during rabi 2013-14 at Junagadh (Gujarat, India) to assess the integrated weed management in popcorn. The weed flora in the experimental site constituted by monocot weeds viz., Brachiaria spp., Asphodelus tenuifolius, Indigofera glandulosa, Echinochloa colona and Dactyloctenium aegyptium, dicot weeds viz., Digera arvensis, Amaranthus viridis, Physalis minima, Launaea nudicaulis, Euphorbia hirta, Chenopodium album, Portulaca oleracea and Phyllanthus niruri and sedge weed Cyperus rotundus. The results indicated that treatments viz., hand weeding (HW) and intercultivation (IC) twice at 15 and 30 days after sowing (DAS), pre-emergence application (PRE) of atrazine 0.5 kg ha^{-1} + HW and IC at 30 DAS and pendimethalin 0.9 kg ha^{-1} as PRE + HW and IC at 30 DAS significantly enhanced growth and yield attributes viz., plant height and dry matter at harvest, cob length, number of cobs per plant, number of grains per cob and grain weight per cob leading to higher grain and fodder yields over unweeded check. These treatments also recorded the lower weed population at 30, 60 DAS and at harvest, dry weight of weed at harvest and weed index as well as higher weed control efficiency along with higher net returns and B:C ratio compared to unweeded check.

***Keywords*:** Hand weeding, herbicide, interculturing, popcorn, *Zea mays* var. everta

Maize is the most versatile crop with wider adaptability in diverse agro-climatic conditions. Due to highest genetic yield potential among cereals, it is known as the "Queen of Cereals". Being a C_4 plant, it is capable of utilizing carbon dioxide and solar radiation more efficiently. In Indian agriculture, it assumes a distinct importance owing to its consumption as food, feed and fodder besides several industrial uses. Popcorn [*Zea mays* L. var. *everta* (Sturtev.) L.H. Bailey] is one of the major speciality corns, which is popular as a snack food in many parts of world. Its kernels are composed of hard starch, when heated, swell and burst. Because of low sugar, fat and calories, it is good food for health. Popped popcorn contains high dietary fibre and anti-oxidants with low calories and fat, and free of sugar and sodium (Vinson, 2012). It has tremendous potential for cultivation because it gives more remuneration to farmers. Nature of weed problem in *rabi* maize is quite different from that of the rainy season maize. In rainy season emergence of maize and weed start simultaneously and first 20-30 days are most critical to crop-weed competition. Contrarily in the winter maize, weed emerges most often after the first irrigation. However, wider row spacing and liberal use of irrigation and fertilizers lead to more growth of weeds (Porwal, 2000). The potential yield losses due to weeds can be as high as about 65% depending on the crop, degree of weed infestation, weed species and management practices (Yaduraju *et al.*, 2006). Pre-emergence application of herbicides may lead to cost effective control of the weeds right from the start which otherwise may not be possible by manual weeding. The present study was carried out to find out economically effective methods of weed control for realizing higher productivity and profitability of *rabi* popcorn.

The experiment was carried out at Instructional Farm, Department of Agronomy, Junagadh Agricultural University, Junagadh (Gujarat) during *rabi*-2013-14. The experiment comprised nine treatments *viz.*, T_1: Atrazine 0.5 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS, T_2: Pendimethalin 0.9 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS, T_3: Atrazine 0.25 kg ha^{-1} + Pendimethalin 0.45 kg ha^{-1} tank-mix as pre-emergence *fb* HW and IC at 30 DAS, T_4: HW and IC at 15 DAS *fb* Atrazine 0.5 kg ha^{-1} as post-emergence at 30 DAS, T_5: HW and IC at 15 DAS *fb* 2,4-D (Na salt) 0.5 kg ha^{-1} as post-emergence at 30 DAS, T_6: HW and IC at 15 DAS *fb* 2,4-D (Na salt) 0.25 kg ha^{-1} + Metsulfuron-methyl 2 g ha^{-1} tank-mix as post-emergence at 30 DAS, T_7: HW and IC at 15 and 30 DAS, T_8: Weed free and T_9: Unweeded control, were evaluated in randomized block design with three replications. The experimental soil was clayey in texture and low in available N and moderate in available phosphorus and potash. The popcorn (cv. Amber) was sown in the last week of November with the seed rate of 15 kg ha^{-1} in the rows spaced 60 cm apart. The crop was raised as per the standard package of practices. Pre-emergence

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herbicides were applied next day of sowing. The spraying was done using knapsack sprayer with flood jet nozzle keeping spray volume of 500 L ha^{-1}. In manual weed control treatments, weeds were uprooted and removed at 30 DAS as per treatments. Interculturing operation was carried out in inter row space through bullock-drawn implement and simultaneous removal of weeds manually in intra row space. In weed free plots, the weeds were removed manually after every 7-10 days for ensuring complete weed free condition. After uprooting of weeds, the weeds were sun-dried completely till reached to constant weight and finally the dry weight was recorded for each treatment and expressed as kg ha^{-1}. Weed control efficiency (WCE) and weed index (WI) were calculated by the formulae suggested by Kondap and Upadhayay (1985) and Gill and Kumar (1969). Net returns and B:C ratio were calculated for drawing conclusion.

Weed flora

The weed flora in the experimental site constituted by monocot weeds *viz*., *Brachiaria* spp. (17.67%), *Asphodelus tenuifolius* L. Cav. (1.79%), *Indigofera glandulosa* L. (1.40%), *Echinochloa colona* L. (1.23%) and *Dactyloctenium aegyptium* Beauv (4.79%), dicot weeds *viz*., *Digera arvensis* Forsk (19.21%), *Amaranthus viridis* L. (2.28%), *Physalis minima* L. (2.77%), *Launaea nudicaulis* L. (1.79%), *Euphorbia hirta* L. (7.77%), *Chenopodium album* L. (19.70%), *Portulaca oleracea* L. (3.52%) and *Phyllanthus niruri* (2.02%) and sedge weed *Cyperus rotundus* L. (21.29%).

Crop growth and yield

Growth and yield attributes as well as cob and fodder yields were significantly influenced by different weed control practices (Table 1). Results showed that significantly higher plant height at harvest (159.4 cm), dry matter $plant^{-1}$ at harvest (179.2 g), cob length (19.0 cm), number of cobs $plant^{-1}$ (2.07), number of grains cob^{-1} (421), grain weight cob^{-1} (86.96 g), grain yield (36.93 q ha^{-1}) and fodder yield (73.50 q ha^{-1}) were recorded under the weed free (T_8), which remained statistically equivalent to HW and IC at 15 and 30 DAS (T_7), atrazine 0.5 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS (T_1) and pendimethalin 0.9 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS (T_2). The improved growth and yield attributes under these treatments might be due to periodical removal of weeds by hand weeding or pre-emergence herbicide supplemented with manual weeding as evidenced by less number of weeds and dry weight of weeds (Table 2), which might have maintained high soil fertility and moisture status by means of less removal of plant nutrients and moisture through weeds. These findings are in close conformity with those reported by Sinha *et al*. (2000), Shekhawat and Gautam (2002), Chopra and Angiras (2007) and Dobariya *et al*. (2014).

Table 1: Effect of different weed control treatments on growth and yield of *rabi* popcorn

Treatments	Plant height (cm)	Dry matter $plant^{-1}$ (g)	Cob length (cm)	Cobs $plant^{-1}$	Grains cob^{-1}	Grain weight cob^{-1} (g)	Grain yield (q ha^{-1})	Fodder yield (q ha^{-1})
Atrazine *fb* HW & IC	150.6	151.4	18.6	1.87	401	79.22	36.22	71.51
Pendimethalin *fb* HW & IC	148.8	150.5	17.9	1.80	397	77.68	35.53	70.74
Atrazine + pendimethalin *fb* HW & IC	140.0	138.9	16.3	1.67	335	65.65	20.14	50.35
HW & IC *fb* Atrazine	141.0	145.8	16.5	1.60	348	74.61	27.78	55.56
HW & IC *fb*2,4-D	144.3	148.8	16.9	1.73	386	67.64	31.25	61.11
HW & IC *fb* 2,4-D + Metsulfuron-methyl	138.3	135.3	16.1	1.60	322	62.24	17.36	38.19
HW & IC twice	158.1	172.2	18.7	2.00	418	80.15	36.46	72.42
Weed free	159.4	179.2	19.0	2.07	421	86.96	36.93	73.50
Unweeded control	112.1	105.8	15.5	1.13	297	61.47	13.19	29.17
SEm (±)	**6.0**	**8.5**	**0.7**	**0.08**	**20**	**3.70**	**2.24**	**3.68**
LSD (0.05)	**17.9**	**25.5**	**2.1**	**0.24**	**61**	**11.10**	**6.72**	**11.05**

Weed parameters

All the treatments significantly reduced the weed population (Table 2) compared to the weedy check. Next to the weed free (T_8), HW and IC at 15 and 30 DAS (T_7) recorded significantly the lowest weed population (Table 2), which remained statistically at par with atrazine 0.5 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS (T_1) and pendimethalin 0.9 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS (T_2). Excluding the weed free (T_8), the lowest dry weight of weed was observed under HW and IC at 15 and 30 DAS (T_7), though it was found statistically at par with atrazine

0.5 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS (T_1). A perusal of data presented in Table 3 indicated that besides the weed free (T_8), HW and IC at 15 and 30 DAS (T_7) contained minimum weed index (WI) with maximum weed control efficiency (WCE), closely followed by atrazine 0.5 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS (T_1) and pendimethalin 0.9 kg ha^{-1} as pre-emergence *fb* HW and IC at 30 DAS (T_2). This might be attributed to the effective control of weeds under these treatments, which reflected in less number of weeds and ultimately lower weed biomass. In addition to this, dense crop canopy might have suppressed weed growth and ultimately less biomass. The combined effect on dry weight of weeds and grain yield under these treatments might have been responsible for excellent weed indices. These findings are in close conformity with those reported by Sinha *et al.* (2003), Verma *et al.* (2009), Shantveerayya and Agasimani (2012) and Mathukia *et al.* (2014).

Table 2: Effect of different weed control treatments on weed parameters

Treatments	Monocot weeds m^{-2}			Dicot weeds m^{-2}			Sedge weeds m^{-2}			Dry weight of weeds (kg ha^{-1})
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	
Atrazine *fb* HW and IC	2.20 (4.36)	1.72 (2.46)	1.42 (1.52)	1.78 (2.67)	1.42 (1.53)	1.38 (1.41)	2.52 (5.85)	1.83 (2.85)	1.77 (2.63)	295
Pendimethalin *fb* HW and IC	2.21 (4.38)	2.04 (3.66)	1.47 (1.66)	1.81 (2.78)	1.64 (2.10)	1.56 (2.00)	2.64 (6.47)	2.06 (3.74)	2.15 (4.12)	417
Atrazine + pendimethalin *fb* HW and IC	3.02 (8.62)	2.81 (7.40)	2.94 (8.16)	2.72 (6.90)	2.73 (6.95)	2.65 (6.53)	3.50 (11.75)	2.88 (7.79)	2.82 (7.45)	556
HW and IC *fb* Atrazine	2.85 (7.67)	2.77 (7.17)	2.76 (7.12)	2.88 (7.79)	2.75 (7.06)	2.76 (7.11)	3.50 (11.75)	3.00 (8.51)	3.02 (8.62)	538
HW and IC *fb*2,4-D	2.99 (8.44)	2.87 (7.74)	2.63 (6.42)	2.69 (6.74)	2.52 (5.85)	2.54 (5.95)	3.15 (9.42)	2.77 (7.17)	2.78 (7.23)	521
HW and IC *fb* 2,4-D + Metsulfuron-methyl	3.78 (13.79)	3.55 (12.10)	3.54 (12.03)	3.61 (12.53)	3.51 (11.82)	3.42 (11.20)	3.94 (15.02)	3.93 (14.94)	3.93 (14.94)	625
HW and IC twice	2.15 (4.12)	1.54 (1.87)	1.15 (0.82)	1.61 (2.09)	1.22 (1.01)	1.19 (1.00)	1.95 (3.30)	1.62 (2.12)	1.66 (2.26)	208
Weed free	0.70 (0.00)	0.69 (0.00)	0.69 (0.00)	0.72 (0.00)	0.70 (0.00)	0.71 (0.00)	0.73 (0.00)	0.71 (0.00)	0.70 (0.00)	0
Unweeded control	5.11 (25.61)	6.98 (48.22)	7.04 (49.06)	5.07 (25.20)	6.63 (43.46)	6.84 (46.29)	6.40 (40.46)	6.68 (44.12)	6.86 (46.56)	1875
SEm (±)	**0.22**	**0.21**	**0.09**	**0.18**	**0.22**	**0.16**	**0.19**	**0.14**	**0.16**	**49**
LSD (0.05)	**0.65**	**0.63**	**0.28**	**0.54**	**0.67**	**0.47**	**0.56**	**0.43**	**0.47**	**147**

Note : *Data subjected to* $\sqrt{x + 0.5}$ *transformation and figures in parentheses are original values*

Economics

The data (Table 3) revealed that maximum net realization of Rs. 53,049 ha^{-1} and B:C of 3.00 was realized with atrazine 0.5 kg ha^{-1} as pre-emergence *fb* HW & IC at 30 DAS, subsequently followed by HW & IC at 15 & 30 DAS, pendimethalin 0.9 kg ha^{-1} as pre-emergence *fb* HW & IC at 30 DAS and weed free treatment. The lowest net realization (Rs. 5,833 ha^{-1}) with B:C value of 1.25 were recorded in the unweeded control.

On the basis of the results obtained from the present field study, it could be concluded that effective and economical management of weeds with higher grain yield of popcorn in *rabi* season can be obtained by pre-emergence application of atrazine 0.5 kg ha^{-1} *fb* HW & IC at 30 DAS or HW & IC at 15 & 30 DAS or pendimethalin 0.9 kg ha^{-1} as pre-emergence *fb* HW & IC at 30 DAS under south Saurashtra Agro-climatic conditions.

Table 3: Effect of different treatments on weed index, weed control efficiency and economics

Treatments	WI (%)	WCE (%)	Gross returns (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Atrazine *fb* HW and IC	1.92	84.26	79,596	26,546	53,049	3.00
Pendimethalin *fb* HW and IC	3.80	77.78	78,129	27,326	50,803	2.86
Atrazine + pendimethalin *fb* HW and IC	45.47	70.37	45,313	26,936	18,376	1.68
HW and IC *fb* atrazine	24.78	71.30	61,111	27,059	34,052	2.26
HW and IC *fb*2,4-D	15.38	72.22	68,611	26,792	41,819	2.56
HW and IC *fb* 2,4-D + Metsulfuron-methyl	52.99	66.67	38,542	26,812	11,730	1.44
HW and IC twice	1.28	88.89	80,158	28,823	51,335	2.78
Weed free	0.00	100.00	81,211	31,897	49,314	2.55
Unweeded control	64.27	0.00	29,306	23,473	5,833	1.25

Market Price:

Commodity		Rs kg^{-1}	Herbicides		Rs kg^{-1} or Rs L^{-1}
Urea	:	6.1	Atrazine	:	500
DAP	:	23.6	Pendimethalin	:	395
Grain price	:	20.0	Metsulfuron-methyl	:	15000
Fodder	:	1.0	2,4-D (SS)	:	42

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