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Integrated weed management in maize (*Zea mays*)

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ABSTRACT

A field experiment was conducted at Almora during 1994–96 to find out most effective control measure for weeds in rainy-season maize *(Zea mays* L.*)* under rainfed conditions. Pre-emergence atrazine (1.25 kg/ha), pendimethalin (1.50 kg/ha) and alachlor (2.00 kg/ha) alone and in combination with 3 post-emergence (30 days after sowing) control measures, viz. hand-weeding, paraquat (0.50 kg/ha) and earthing up the crop were compared with weed-free and weedy check treatments. None of the pre-emergence herbicides alone provided desired control of weeds. However, alachlor proved most effective [weed-control efficiency (WCE) 65.0%], followed by pendimethalin (WCE 63.1%) and atrazine (WCE 58.9%). Atrazine was more effective against *Ageratum conyzoides* L. and less effective against *Echinochloa colonum* (L.) Link and *Brachiaria ramosa* stapf than pendimethalin or alachlor. Inclusion of all post-emergence weed-control measures in any pre-emergence herbicide markedly improved WCE, yield attributes and grain yield. However, earthing up the crop proved most effective, followed by hand-weeding and paraquat. Highest grain yield (4,080 kg/ha), superior yield attributes, net return (Rs.4,585/ha) and benefit : cost ratio (1.30) were recorded under alachlor+earthing up the crop. This treatment being at par with weed-free also had higher WCE than all treatments.

Key words : Integrated weed management, Maize, Herbicides

Rainy-season *(kharif)* maize suffers heavy yield losses due to weed infestation owing to congenial environmental conditions for luxurious weed growth coupled with wider row planting and slow growth at early stage. Yield losses due to weeds varied 28–93%, depending on the type of weed flora and their intensity stage, nature and duration of crop–weed competition (Sharma and Thakur, 1998). Atrazine, pendimethalin and alachlor are widely used for control of weeds in maize. However, atrazine did not provide effective control of *Echinochloa* spp., *Digitaria sanguinalis, Panicum* spp. or *Setaria* spp. (Gragnac, 1978) while pendimethalin and alachlor were less effective than atrazine against *A. conyzoides* (Thakur and Singh, 1989; Saini and Angiras, 1998). Uncontrolled group of weed flora present in

the field takes over others and may offer severe competition to crop. Moreover, continuous use of single herbicide leads to evolution of herbicide-resistant weed species and shift in weed flora (Sinha and Sinha, 1970; Thakur and Sharma, 1996). Under such circumstances, to get effective control of composite weed flora, integrated approach of weed management is the best choice. Since information on best approach of integrated weed management in maize under hill conditions is meagre, the present investigation was therefore undertaken.

MATERIALS AND METHODS

A field experiment was conducted under rainfed conditions during *kharif* 1994, 1995 and 1996 at the Experimental Farm, Hawalbagh (29° 36' N, 79° 40' E, 1,250 m amsl), Almora, Uttaranchal. The soil of experimental site was loamy clay in texture, acidic in reaction (pH 6.0), low in available N (154 kg/ha), medium in available P (16.8 kg/ha) and available K (271 kg/ha). A set of 14 treatments, comprising the pre-emergence application of atrazine (1.25 kg/ha), pendimethalin (1.50 kg/ha) and alachlor (2.00 kg/ha) alone and in combination with 3 post-emergence [30 days after sowing (DAS)], weed-control measures, viz. hand weeding (HW), paraquat (0.50 kg/ha) and earthing up the crop, were compared with weed-free and weedy check treatments. The experiment was laid out in randomized block design with 3 replications. A short-duration maize cv. 'VL Makka 16' was sown on 7 July during 1994 and 27 June 1995 and 1996 in rows 60 cm apart, using 20 kg/ha seeds. Crop was fertilized 45 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha as basal dose and remaining 45 kg/ha N was top-dressed 30 DAS. The N, P and K nutrients were supplied through urea, single superphosphate and muriate of potash respectively. Thinning was done 15 DAS to maintain plant-to-plant distance of 25 cm. Atrazine, pendimethalin and alachlor in calibrated amounts, dissolved in water (800 litres/ha) were sprayed as pre-emergence to weeds on the next day of sowing using flat-fan nozzle during all years. Directed spray of paraquat was done in inter-row spaces of maize using plastic hood of 50 cm width, fitted at the nozzle of the sprayer. In weed-free treatment, in all 5 weedings were done 15, 30, 45, 60 and 75 DAS. Two quadrats of 0.5 m × 0.5 m size were placed randomly in each plot at 55 days stage and weeds fallen in the quadrats were removed and counted species-wise. After drying in hot-air oven (70 ± 1 °C for 72 hr), weed dry weight was recorded and reported as per square meter. Weed-control efficiency (WCE) was also calculated. The climate of the region (mid-hills) is subtemperate, characterized by moderate summers with well-distributed rainfall and congenial to maize crop. Crop received total rainfall of 718.2, 745.7 and 449.7 mm in 58, 52 and 36 rainy days during 1994, 1995 and 1996 respectively. The mean weekly range of maximum and minimum temperatures during 1994, 1995 and 1996 crop seasons was 26.6–31.3, 25.1–30.6, 25.3–31.0 and 16.3–21.5, 17.9–21.9, 17.6–21.0° C respectively. Crop was raised with recommended package of practices.

RESULTS AND DISCUSSION

Weed flora

Weeds of experimental field were: *Echinochloa colonum* (L.) Link, *Brachiaria ramosa* (L.), *Digitaria sanguinalis* (L.) Scope, *Dactyloctenium aegyptium* Beauv., *Eleusine indica* Garetn., *Setaria glauca* Beauv., *Sorghum halepense* (L.) Pers. and *Panicum* spp. among grasses; *Ageratum conyzoides* L., *Galinsoga parviflora* Cav., *Commelina benghalensis* L., *Lindernia cilata* (Colsm) Penoid, *Polygonum hydropiper* L., *Euphorbia geniculata* Forsk and *Oxalis latifolia* H.B.K. among non-grassy weeds; and *Cyperus rotundus* L. among sedges. Grassy, non-grassy and sedges constituted 71.6 to 77.5, 19.6 to 23.0 and 1.8 to 5.8% respectively to total weed population in weedy check plot in different years. *E. colomum* and *B. ramosa* were the pre-dominant weeds, contributing 60.8 to 67.8 and 21.1 to 26.5%, respectively, to total grassy weeds during different years. *Ageratum conyzoides*, the predominant weed among non-grassy weeds, alone constituted 66.3 to 83.7% to total non-grassy weeds in different years. The *C. rotundus* was the only weed among the sedges.

Effect on weeds

All the weed-control treatments proved significantly effective in reducing the

Table 1. Effect of different treatments on weed population, weed dry weight and weed-control efficiency in maize (mean of 3 years).

Treatment	Wood population (No./m²)	Weed dry weight (g/m²)				Weed-control efficiency (%)
		Echinochloa colonum	*Brachiaria ramosa*	*Ageratum conyzoides*	Total	
T_1	314	86.8	41.9	8.2	204.6	58.9
T_2	260	23.4	15.6	29.8	94.4	81.4
T_3	164	46.5	11.0	30.9	119.1	76.7
T_4	189	18.8	7.9	20.6	62.4	87.1
T_5	285	35.3	17.3	69.4	184.4	63.1
T_6	239	24.2	9.8	33.8	89.1	82.5
T_7	152	39.4	10.0	38.2	99.3	80.7
T_8	184	18.7	9.6	22.3	58.1	88.5
T_9	248	31.8	12.8	63.7	175.7	65.0
T_{10}	200	25.2	12.1	32.1	90.0	82.2
T_{11}	132	36.5	10.0	21.4	100.7	80.4
T_{12}	155	17.1	6.3	19.7	53.1	89.6
T_{13}	0	0	0	0	0	100
T_{14}	625	305.8	72.8	59.1	491.4	
CD (P = 0.05)	63	31.3	10.1	15.4	34.2	

T_1, Atrazine 1.25 kg/ha pre-em; T_2, T_1 + HW (30 DAS): T_3, T_1 + paraquat 0.50 kg/ha (30 DAS); T_4, T_1 + earthing up the crop (30 DAS; T_5, pendimethalin 1.50 kg/ha pre-em; T_6, T_5 + HW (30 DAS); T_7, T_5 + paraquat 0.50 kg/ha (30 DAS); T_8, T_5 + earthing up the crop (30 DAS); T_9, alachlor 2.00 kg/ha pre em.; T_{10}, T_9 + HW (30 DAS); T_{11}, T_9 + paraquat 0.50 kg/ha (30 DAS); T_{12}, T_9 + earthing up the crop (30 DAS); T_{13}, weed-free; T_{14}, weedy check

population and dry weight of weeds compared with weedy check (Table 1). Paradkar and Sharma (1993) and Thakur and Sharma (1996) also reported similar results. Among pre-emergence herbicides alone, lowest total weed population and dry weight were recorded under alachlor (2.00 kg/ha), followed by pendimethalin (1.50 kg/ha) and atrazine (1.25 kg/ha). Inclusion of all the post-emergence weed-control measures in any pre-emergence herbicide significantly reduced total population and dry weight of weeds compared with their respective pre-emergence herbicides alone except total weed population due to any pre-emergence herbicide, followed by HW. Among integrated weed-control measures, any pre-emergence herbicide, followed by paraquat (0.50 kg/ha) recorded the lowest population of weeds; however, total dry weight of weeds was lowest under any pre-emergence herbicide, followed by earthing up the crop. Higher weed dry weight under paraquat-treated plots than earthing up the crop may be attributed to uncontrolled weed growth in intra-row spaces of maize plants. Dry weight of individual weed species revealed that atrazine was more effective than pendimethalin or alachlor against *A. conyzoides,* while alachlor, followed by pendimethalin proved more effective than atrazine in controlling the *E.*

Table 2. Effect of different treatments on yield attributes, yileds and monetary return of maize (mean dala of 3 years)

Treatment	Plant height (cm)	Number of cobs ('000 ha)	Cob length (cm)	Cob girth (cm)	Grains/ cob	1,000-grain weight (g)	Grain yield (kg/ha)	Net returns (Rs.000/ ha)	Benefit : cost ratio
T_1	215.8	65.4	11.5	11.8	165	265.1	2,747	1,574	1.12
T_2	220.9	69.2	12.0	12.3	189	270.1	3,413	2,392	1.16
T_3	220.5	70.3	11.8	12.0	184	268.5	3,223	2,732	1.20
T_4	221.7	74.2	12.4	12.5	194	270.9	3,779	3,747	1.25
T_5	214.9	65.1	11.6	11.9	178	266.2	2,957	1,780	1.13
T_6	222.0	70.5	12.1	12.4	183	269.5	3,720	2,866	1.18
T_7	218.8	70.2	12.0	12.3	187	268.6	3,463	2,529	1.17
T_8	223.6	70.6	12.3	12.6	206	271.0	3,903	3,548	1.22
T_9	216.0	66.3	11.7	12.0	176	267.2	3,053	2,825	1.22
T_{10}	221.6	72.4	12.2	12.3	192	270.3	3,663	3,168	1.21
T_{11}	224.0	70.4	12.1	12.2	189	269.1	3,477	3,281	1.23
T_{12}	224.5	72.7	12.7	12.6	210	271.5	4,080	4,585	1.30
T_{13}	222.7	73.0	12.6	12.6	207	270.6	3,953	1,374	1.07
T_{14}	166.7	33.6	7.5	8.6	81	253.1	633	-5,186	-0.42
CD (P=0.05)	16.4	12.7	0.6	0.5	21	10.2	876	632	0.05

T_1, Atrazine 1.25 kg/ha pre-em; T_2, T_1 + HW (30 DAS): T_3, T_1+paraquat 0.50 kg/ha (30 DAS); T_4, T_1 + earthing up the crop (30 DAS; T_5, pendimethalin 1.50 kg/ha pre-em; T_6, T_5 + HW (30 DAS); T_7, T_5 + paraquat 0.50 kg/ha (30 DAS); T_8, T_5 + earthing up the crop (30 DAS); T_9, alachlor 2.00 kg/ha pre em.; T_{10}, T_9 + HW (30 DAS); T_{11}, T_9 + paraquat 0.50 kg/ha (30 DAS); T_{12}, T_9 + earthing up the crop (30 DAS); T_{13} weed-free; T_{14}, weedy check

colonum and *B. ramosa*. Thakur and Singh (1989) and Saini and Angiras (1998) also recorded similar results. Weed-control efficiency (WCE) of different treatments varied from 58.9 to 97.8%. Among pre-emergence herbicides alone, alachlor was most effective against weeds (WCE 65.0%), followed by pendimethalin (WCE 63.1%) and atrazine (WCE 58.9%). Thakur and Singh (1989) also reported higher WCE of pendimethalin than atrazine. Inclusion of all post-emergence weed-control measures in any pre-emergence herbicide markedly enhanced the weed-control efficiency; however, earthing up the crop proved most effective, followed by HW and paraquat. Among integrated weed-management practices, highest weed-control efficiency (89.6%) was recorded under alachlor + earthing up the crop the crop.

Effect on crop

Yield attributes and grain yield showed that unweeded crop had significantly lowest plant height (Table 2). All the post-emergence control measures superimposed over pre-emergence herbicides though brought enhancement in plant height; however, failed to attain significance compared with respective pre-emergence herbicides alone. Any pre-emergence herbicide followed by earthing up the crop the crop (30 DAS) produced taller plants than HW or paraquat. All the weed-control treatments produced significantly more number of cobs than weedy check. Number of cobs further increased owing to inclusion of all the post-emergence weed-control measures in any pre-emergence herbicide compared with respective pre-emergence herbicide alone. However, maximum increase in number of cobs was recorded due to earthing up the crop. Cob length and cob girth also followed similar pattern. Grains/cob were also influenced significantly by different weed-control treatments. Among the pre-emergence herbicides alone, alachlor produced higher grains/cob, followed by pendimethalin and atrazine; however, differences were non-significant among themselves. Any pre-emergence herbicides followed by earthing up resulted in significantly more grains/cob than respective pre-emergence herbicide alone. Significantly lowest 1,000-grain weight was recorded under weedy check. However, 1,000-grain weight did not differ significantly among all other weed-control treatments. Singh *et al.* (1985) also reported higher test weight under weed-control treatments than weedy check.

Compared to weed-free condition, the season-long crop–weed competition reduced the grain yield by 84.3%. All the weed-control measures resulted in significantly higher grain yield than weedy check. All the pre-emergence herbicides alone being at par failed to provide potential maize yield. However, alachlor resulted in the highest grain yield, followed by pendimethalin and atrazine. Highest grain yield was recorded under the alachlor + earthing up the crop. Increase in grain yield owing to inclusion of post-emergence weed-control measures in pre-emergence herbicides varied from 13.9 to 38.2% over pre-emergence herbicides alone, irrespective of herbicides. Earthing up the crop was significantly superior to HW or paraquat,

which increased grain yield by 38.2 32.2 and 33.6% as against 24.2, 25.9 and 20.0% due to HW; 17.7, 17.2 and 13.9% due to paraquat over atrazine, pendimethalin and alachlor alone respectively. Higher yield under earthing up the crop than HW or paraquat may be attributed to better drainage facility to crop, efficient utilization of resources, particularly N, as earthing up the crop was immediately followed by N top-dressed. Higher yield under integrated weed-control treatments may be attributed to checked weed growth due to application of pre-emergence herbicides during early stages and due to post-emergence weed-control measures at later stages, resulting in reduced crop–weed competition and thereby providing superior values of yield attributes.

Monetary returns

All the weed-control treatments were superior in terms of monetary returns to unweeded check. Among pre-emergence herbicides, atrazine and pendimethalin being at par proved significantly inferior to alachlor for both net returns as well as benefit : cost ratio. Inclusion of all the post-emergence weed-control measures in any pre-emergence herbicide had more monetary advantage than respective pre-emergence herbicide alone. Among all the weed-control practices, alachlor followed by earthing up the crop recorded the highest net returns and benefit : cost ratio, while lowest net returns and benefits: cost ratio was recorded under the weed-fee condition.

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