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Management of diverse weed flora in maize under Kangra valley conditions of Himachal Pradesh

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ABSTRACT

Twelve weed control treatments, *viz*. atrazine 1.0 kg/ha (2 days after sowing, DAS), metribuzin 0.25 kg/ha (2 DAS), oxyflourfen 0.15 kg/ha (2 DAS) alone and in integration with hoeing at 30 DAS, atrazine 1.0 kg/ha (2 DAS) followed by (*fb*) atrazine 0.5 kg/ha (30 DAS), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (2 DAS), intercropping of cowpea and mung bean, hand weeding thrice (15, 30 and 45 DAS) and weedy check were tested in maize during 2012 and 2013 under Kangra valley conditions of Himachal Pradesh. Herbicides alone, in combination with hoeing and sequential application significantly reduced the count and dry weight of weeds and increased number of cobs, 100-grain weight and grain yield of maize over the intercropping treatments. Maize grain yield was negatively associated with weed count (r= -0.819**) and weed dry weight (r = -0.791**) and positively correlated with cobs number (r = 0.950**), cob length (r = 0.879**) and 100-seed weight (r = 0.836**). With unit increase in weed count, the grain yield of maize decreased by 75.5 kg/ha. Un-checked weed growth reduced the grain yield of maize by 60.7%. Based on the results, metribuzin 0.250 kg/ha, atrazine 1.00 kg/ha, atrazine 1.0 kg/ha *fb* atrazine 0.5 kg/ha (30 DAS), oxyflourfen 0.15 kg/ha, atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha and metribuzin 0.25 kg/ha *fb* hoeing (30 DAS) were recommended for effective management of diverse weed flora in maize under Kangra valley conditions of Himachal Pradesh.

Key words: Dry weight, Economic thresholds, Grain yield, Impact assessment, Maize, Weed management

Maize is grown at wider row spacing which results in greater infestation of weeds in the early stages. Diverse weed flora are composed of grasses, sedges and broad-leaved species. Atrazine is the most popular herbicide for controlling weeds in maize. The repeated application of atrazine has resulted in increased frequency of *Ageratum*, *Commelina* and *Brachiaria* (Kumar *et al*. 2012). In order to optimize weed control efficacy and minimize the application costs, the use of combinations of pre- and post-emergence herbicides as well as herbicide mixtures has been advocated for season-long weed control. Intercropping has also been recognized as an effective tool to suppress weeds in maize (Sood *et al*. 2016). In view of the above, the present investigation was carried out to develop practices for diverse weed flora management in maize.

MATERIALS AND METHODS

A field trial was conducted during the *Kharif* seasons of 2012 and 2013 at Shivalik Agricultural Research and Extension Centre, Kangra (32^{o}092 N latitude, 76^{o}222 E longitude and 615 m altitude). The site lies in warm sub-humid zone of Himachal Pradesh (NARP zone II), which is characterized by mild summers and severe winters. The average total annual rainfall was 1539 mm, out of which 1216 mm was received during SW monsoon. The soil of the experimental site was silty clay loam in texture, neutral in reaction (pH 6.8) and medium in available N (335 kg/ha), P (20 kg/ha) and K (201 kg/ha). Twelve weed control treatments *viz*. atrazine 1.0 kg/ha (2 days after sowing, DAS), metribuzin 0.25 kg/ha (2 DAS), oxyflourfen 0.15 kg/ha (2 DAS) alone and in integration with hoeing at 30 DAS, atrazine 1.0 kg/ha (2 Das) followed by (*fb*) atrazine 0.5 kg/ha (30 DAS), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (2 DAS), cowpea and mung bean intercrops, hand weeding thrice (15, 30 and 45 DAS) and weedy check were tested in randomized block design with three replications. Seed of maize hybrid '*Pro Agro 4640*' was sown at 20 kg/ha on 5th June 2012 and 1st June 2013 keeping row to row spacing of 60 cm and plant to plant spacing of 20 cm. The crop was fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha through urea, single super phosphate and muriate of potash, respectively. The required quantity of half N and whole P_2O_5 and 40 kg K_2O was drilled at sowing. The remaining half N was band placed in two equal splits

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at knee high and tasseling stages. Herbicides as per treatment were applied with backpack power sprayer using 600 litre water/ha.

Weed dry weight (60 DAS and at harvest) was recorded using a quadrate of 50 x 50 cm. Yields were harvested from net plot area (4.5 x 3.6 m). The data were subjected to statistical analysis by analysis of variance (ANOVA) for the randomized block design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level.

Economic threshold (=economic injury levels), the weed density at which the cost of treatment equals the economic benefit obtained from that treatment, was calculated after Uygur & Mennan (1995) and Stone and Pedigo (1972).

Uygur and Mennan:

$$Y = [\{(100/He*Hc)+A_C\}/(Gp*Yg)]*100$$

where, Y is percent yield losses at a different weed density; He, herbicide efficiency; Hc, herbicide cost; Ac, application cost of herbicide; Gp, grain price and Ywf, yield of weed free.

Stone and Pedigo:

Economic threshold = Gain threshold/ Regression coefficient

where, gain threshold = Cost of weed control (Hc+Ac)/Price of produce (Gp), and regression coefficient (b) is the outcome of simple linear relationship between yield (Y) and weed density/ biomass (x), Y = a + bx.

The different impact indices were worked out after Rana and Kumar (2014).

Additionally, 'overall impact index' was determined, by calculating firstly the 'unit value' where the value under a particular treatment of a parameter was divided by the respective arithmetic mean of treatments for that parameter as given below:

$$U_{ij} = \frac{V_{ij}}{AM_j}$$

where Uij is the unit value for ith treatment corresponding to jth parameter, Vij is the actual measured value for ith treatment and jth parameter and AMj is the arithmetic mean value for jth parameter.

Secondly, the overall performance index was calculated as an average of unit values (Uij) of all the parameters under consideration:

$$OI_i = \frac{1}{N}\sum_{i=1}^{N} U_{ij}$$

where OIi is the overall impact index for ith treatment and N is the number of parameters used in deriving overall impact index.

RESULTS AND DISCUSSION

Weed count and dry weight

Major weeds of the experimental field were *Echinochloa colona*, *Cyperus iria*, *Equisetum arvense*, *Setaria glauca*, *Paspalum* sp, *Ageratum conyzoides* and *Bidens pilosa*. All treatments were significantly superior to weedy check in reducing the count and dry weight of weeds both at 60 DAS and at harvest (**Table 1**). The lowest count and dry weight of weeds were recorded under hand weeding thrice. The herbicides alone and in combination with hoeing were superior to intercropping treatments in reducing count and dry weight of weeds. Superiority of atrazine (Hawaldar and Agastimani 2012), metribuzin (Patel *et al*. 2006), oxyflourfen alone and in integration with hand weeding/hoeing (Hawaldar and Agastimani 2012) and as a sequential application (Kumar *et al*. 2012) in maize is well established.

Yield

Growth and yield of maize differed significantly due to weed control treatments (**Table 2**). Uninterrupted competition by weeds significantly reduced the effective maize plant population. Cowpea vines trailed around the maize and brought down the effective maize population. Similarly, effective population of maize under maize + mungbean intercropping was significantly lower than hand weeding. Plant height was significantly more in treatments than the weedy check. Intercropping of cowpea and mungbean, oxyflourfen, oxyflourfen *fb* hoeing and atrazine *fb* atrazine had shorter plants than hand weeding. Number of cobs was significantly more in herbicidal treatments and hand weeding. Number of cobs under cowpea intercropping was lower than the weedy check. All treatments were significantly superior to weedy check in increasing the 100-grain weight. Atrazine + pendimethalin, metribuzin *fb* hoeing and atrazine had higher 100-grain weight than the other treatments. All treatments except intercropping of cowpea and mungbean had higher maize grain yield over weedy check. All herbicidal treatments were comparable to hand weeding thrice in increasing the yield.

Maize grain yield was found to be negatively associated with weed count (r = -0.819**) and weed dry weight (r = -0.791**) and was positively associated with plant population (r = 0.874**), cobs number (r = 0.950**), cob length (r = 0.879**) and 100-seed weight (r = 0.836**). The increases in yield attributes and yield due to effective control of weeds with herbicides alone, in combination and herbicides + interculture/hand weeding are documented (Rana *et al.* 1998, Hawaldar and Agastimani 2012, Kumar *et al.* 2011, 2012). The linear relationship between weed count and dry weight at 60 DAS (x, almost the end of critical period of crop weed competition and grain yield (Y) of maize is given here as under:-

Weed count

Y = 7997 – 75.5x (R^2= 0.671)...................(1)

Weed dry weight

Y = 7885 – 75.1x (R^2= 0.626).....................(2)

Equation 1 and 2 explain that over 60% of the variation in grain of maize due to count and dry weight of weeds during the critical period of crop-weed competition could be explained by these regression equations. With unit increase in weed count/m^2 or weed dry weight (g/m^2), the grain yield of maize reduced by 75 kg/ha.

Economic threshold

The economic threshold levels of weeds at the current prices of treatment application and the crop production on the basis of weed infestation during the time of critical period of competition in maize have been given in **Table 3**. The economic threshold levels varied from 7.8 – 85/m^2 and 7.6-90.3 g/m^2 when determined after Stone and Pedigo and 2.1 to 25.7 after Uygur and Mennan. It indicates that any increase in cost of weed control would lead to higher values of economic threshold, whereas an increase in price of crop produce would result in lowering the

Table 1. Effect of treatments on count and dry weight of weeds in maize at 60 DAS

Treatment	Dose (kg/ha)	Time (DAS)	Weed count (no./m^2)		Weed dry weight (g/m^2)	
			2012	2013	2012	2013
Atrazine	1	2	5.3(27.3)	5.3(27.3)	5.3(28.2)	5.2(27.0)
Metribuzin	0.25	2	4.7(23.0)	5.1(26.7)	5.3(30.9)	5.0(25.6)
Oxyflourfen	0.15	2	5.2(27.0)	5.5(29.7)	5.9(35.0)	5.5(29.4)
Atrazine *fb* atrazine	1.0 *fb* 0.5	2 *fb* 25-30	5.4(28.3)	5.4(28.7)	5.5(29.7)	5.4(28.5)
Atrazine *fb* hoeing	1	2 *fb* 25-30	6.1(36.3)	6.4(40.0)	5.9(34.9)	6.1(37.2)
Metribuzin *fb* hoeing	0.25	2 *fb* 25-30	5.7(32.3)	6.0(35.3)	4.6(21.1)	6.3(39.0)
Oxyflourfen *fb* hoeing	0.15	2 *fb* 25-30	5.1(26.0)	5.2(26.7)	5.0(25.0)	5.4(28.9)
Atrazine + pendimethalin	1.0 + 0.5	2	6.3(40.3)	6.2(37.7)	5.6(31.6)	6.2(38.5)
Cowpea inter-cropping	-		7.4(56.0)	7.8(61.0)	7.0(49.0)	8.0(63.4)
Mungbean inter-cropping	-		7.1(53.7)	7.9(61.7)	6.3(40.4)	7.9(62.4)
Hand weeding		15, 30, 45	3.0(8.7)	3.5(12.0)	1.8(2.9)	3.0(8.8)
Weedy			9.2(83.7)	9.3(86.7)	9.1(81.6)	9.3(86.7)
LSD (p=0.05)			1.9	0.8	1.5	0.7

Data transformed to square root transformation; Values given in parentheses are the means of original data

Table 2. Effect of treatments on growth, yield attributes and yield of maize

Treatment	Dose (kg/ha)	Plant population ($x10^3$/ha)		Plant height (cm)		Cobs ($x10^3$/ha)		Cob length (cm)		100-grain weight (g)		Grain yield (t/ha)	
		2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Atrazine	*1*	71.1	71.1	206.7	219.7	63.7	65.9	23.8	22.8	40.5	39.4	5.83	5.74
Metribuzin	0.25	73.7	72.2	200.7	216.7	69.3	68.1	24.3	22.9	36.3	38.4	6.60	6.16
Oxyflourfen	0.15	71.9	71.5	162.0	192.0	64.8	67.8	22.2	23.1	36.1	35.9	6.02	5.82
Atrazine *fb* atrazine	1.0 *fb* 0.5	74.1	72.6	165.7	178.3	67.8	71.5	22.9	22.9	31.9	31.6	6.24	6.00
Atrazine *fb* hoeing	1	70.4	69.6	185.7	197.0	63.0	67.8	23.5	23.1	33.0	37.7	6.09	6.05
Metribuzin *fb* hoeing	0.25	71.5	70.4	201.3	204.3	61.1	67.4	25.6	22.8	42.3	41.5	6.54	6.33
Oxyflourfen *fb* hoeing	0.15	72.6	74.1	160.3	164.7	65.2	64.4	22.5	23.6	31.6	31.3	6.00	5.93
Atrazine + pendimethalin	1.0 + 0.5	66.7	73.7	203.7	206.0	61.1	67.4	24.5	23.3	40.8	40.2	6.51	6.08
Cowpea inter-cropping	-	47.4	44.8	174.3	174.3	18.1	28.9	23.1	20.0	24.2	24.0	1.35	1.24
Mungbean inter-cropping	-	65.9	69.6	171.3	169.3	31.5	67.4	21.7	19.7	29.1	27.7	2.74	2.25
Hand weeding	-	75.2	73.7	195.0	200.0	63.0	69.6	22.9	22.6	34.2	32.4	6.10	6.08
Weedy check	-	51.1	48.1	151.0	147.0	24.4	38.5	20.7	20.2	21.9	20.6	2.58	2.48
LSD (p=0.05)		4.6	3.5	13.4	16.0	5.1	3.0	1.9	1.4	3.7	2.1	0.50	0.22

economic threshold. Hand weeding had higher values of economic threshold than the herbicidal treatments due to higher wages. The lowest application cost was under metribuzin alone and thus the lowest values of economic threshold.

Economics

Due to higher grain and stover yield, gross returns under hand weeding thrice and herbicidal treatments were significantly more over weedy check (**Table 3**). However, due to low yield of maize and intercrop, intercropping did not significantly increase total gross returns over weedy check. Integrated weed control treatments were more or less similar to hand weeding thrice, but due to higher cost under the latter, net returns over weedy check (NRwc) were more. The highest net returns due to weed control (NRwc) were accrued under metribuzin followed by atrazine + pendimethalin, metribuzin *fb* hoeing and atrazine *fb* atrazine. MBCR was also highest under metribuzin 0.25 kg/ha followed by atrazine, oxyflourfen, atrazine + pendimethalin and atrazine *fb* atrazine. The results indicated that hoeing in combination with herbicides increased the cost of treatment and thus lowered marginal benefit: cost ratio.

Impact assessment

Hand weeding thrice resulted in highest weed control efficiency due to effective frequent removal (**Table 4**). All herbicidal treatments were superior to intercropping of cowpea and mungbean in increasing weed control efficiency. Weed persistence index (WPI) was lowest and crop resistance index (CRI) was highest under the hand weeding thrice. Since maize + legume intercropping system was grown

Table 3. Economics of weed control and economic threshold of weeds

Treatment	Dose	Gt	Et (S and P) Count	Et (S and P) Weight	Et (U and M)	CWC	GRwc	NRwc	MBCR
Atrazine	*1*	94	7.8	8.3	3.6	1404	62470	61066	43.49
Metribuzin	0.25	86	7.2	7.6	2.1	1287	73899	72612	56.41
Oxyflourfen	0.15	133	11.1	11.8	3.4	1995	65016	63021	31.60
atrazine *fb* atrazine	1.0 *fb* 0.5	174	14.5	15.4	6.7	2616	68965	66349	25.36
Atrazine *fb* hoeing	1	377	31.4	33.4	7.5	5654	67973	62319	11.02
Metribuzin *fb* hoeing	0.25	369	30.8	32.7	6.1	5537	74992	69455	12.54
Oxyflourfen *fb* hoeing	0.15	416	34.7	36.8	8.0	6245	65940	59695	9.56
Atrazine + pendimethalin	1.0 + 0.5	171	14.3	15.1	4.8	2567	72304	69738	27.17
Cowpea inter-cropping	-	233	19.4	20.6	25.7	3500	4376	876	0.25
Mungbean inter-cropping	-	233	19.4	20.6	21.8	3500	7070	3570	1.02
Hand weeding		1020	85.0	90.3	16.8	15300	68304	53004	3.46
Weedy check		0	0.0	0.0	0.0	0	0	0	-

Gt - gain threshold; Et - Economic threshold; Et - (S and P) - economic threshold after Stone and Pedigo; Et (U and M) - Economic threshold after Uyger and Mennan; GRwc - Gross return over weedy check (INR/ha); CWC - cost of weed control (INR/ha); NRwc - Net return over weedy check; MBCR - marginal benefit cost ratio;

Table 4. Impact assessment indices

Treatment	Dose (kg/ha)	WCE	WPI	CRI	WMI	AMI	IWMI	HEI	WI	Win	Cin	OIi
Atrazine	1.00	67.5	1.02	6.97	3.40	2.40	2.90	3.92	5.0	79.4	20.6	1.18
Metribuzin	0.25	68.6	1.15	7.51	3.80	2.80	3.30	4.53	-4.8	77.3	22.7	1.34
Oxyflourfen	0.15	64.3	1.15	6.12	3.79	2.79	3.29	3.50	2.8	79.8	20.2	1.16
Atrazine *fb* atrazine	1.0 *fb* 0.5	66.0	1.03	7.00	3.70	2.70	3.20	4.11	-0.6	79.5	20.5	1.17
Atrazine *fb* hoeing	1.00	56.2	0.96	5.60	4.20	3.20	3.70	3.27	0.3	84.5	15.5	1.07
metribuzin *fb* hoeing	0.25	62.3	0.90	7.13	3.96	2.96	3.46	4.33	-5.7	82.7	17.3	1.14
Oxyflourfen *fb* hoeing	0.15	68.5	1.04	7.37	3.47	2.47	2.97	4.24	2.0	78.2	21.8	1.09
Atrazine + pendimethalin	1.00 + 0.50	56.3	0.91	5.98	4.26	3.26	3.76	3.58	-3.4	84.7	15.3	1.16
Cowpea inter-cropping	-	32.3	0.97	0.77	1.54	0.54	1.04	-0.73	78.7	92.7	7.3	0.30
Mungbean inter-cropping	-	35.6	0.90	1.61	2.54	1.54	2.04	-0.02	59.0	89.5	10.5	0.50
Hand weeding		90.5	0.57	34.72	2.59	1.59	2.09	20.29	0.0	58.1	41.9	1.67
Weedy check		0.0	1.00	1.00	0.00	0.00	0.00	0.00	58.5	94.5	5.5	0.23

WCE - weed control efficiency (%); WPI - Weed persistence index; CRI - Crop resistance index; WMI - Weed management index; AMI - Agronomic management index; IWMI - Integrated Weed management index; HEI - Treatment/Herbicide efficiency index; WI - weed index; Win - Weed intensity; Cin - Crop intensity; OIi - overall impact index without any herbicidal/manual control, crop resistance index (CRI) due to poor control of the weeds were lower than all the herbicidal/IWM treatments. Weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) were higher in herbicidal/IWM treatments than the hand weeding and intercropping treatments. Highest WMI, AMI and IWMI were found under atrazine + pendimethalin and lowest under cowpea intercropping. Treatment/ herbicidal efficiency index was highest under hand weeding thrice followed by metribuzin, metribuzin *fb* hand weeding, oxyflourfen *fb* hoeing. Intercropping gave negative values of TEI/HEI and thereby maximum reduction in yield in comparison to weed free/hand weeding thrice. Weed intensity was lowest and crop intensity was more in hand weeding thrice than other treatments. Highest weed intensity and lowest crop intensity were recorded in weedy check. Overall impact index (OIi), which was drawn taking together different indices as well as per cent control of weeds, yield and economic parameters to have a valid inference and conclusion. The OIi was highest under hand weeding thrice followed by metribuzin, atrazine, atrazine *fb* atrazine, oxyflourfen, atrazine + pendimethalin, metribuzin *fb* hand weeding, oxyflourfen *fb* hand weeding and atrazine *fb* hand weeding.

It was concluded that metribuzin 0.250 kg/ha, atrazine 1.0 kg/ha, atrazine 1.0 kg/ha *fb* atrazine 0.75 kg/ha (30 DAS), oxyflourfen 0.15 kg/ha, atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha, metribuzin 0.250 kg/ha *fb* hand weeding (30 DAS), oxyflourfen 0.15 kg/ha *fb* hand weeding (30 DAS) or atrazine 1.0 kg/ ha *fb* hand weeding (30 DAS) may be recommended for effective weed management in maize under Kangra valley conditions of Himachal Pradesh.

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