



Weed management strategies in maize (*Zea mays*): Effect on weed dynamics, productivity and economics of the maize- wheat (*Triticum aestivum*) cropping system in Indo-gangetic plains

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ABSTRACT

A field experiment was conducted to evaluate the efficacy of different herbicidal treatments along with cowpea (*Vigna unguiculata* (L.) Walp.) as live mulch crop as one of the treatments in preceding maize (*Zea mays* L.) and their residual effects on succeeding wheat (*Triticum aestivum* L.) crop during 2010-11 and 2011-12. In maize field, metribuzin/atrazine was not found effective to control *Dactyloctenium colonum*, however, application of metribuzin 0.25 kg/ha as pre emergence (PE) followed by one hand weeding at 21 DAS was found most effective in controlling this weed. Metribuzin 0.25 kg/ha as PE + one hand weeding (HW) and maize + cowpea intercropping resulted in significantly lowest weed index which remained at par with atrazine as PE + one HW. However, after pooled analysis of results significantly highest grain yield (6 785 kg/ha) of maize was obtained with two HW, while highest grain yield of succeeding wheat (6 191 kg/ha) was obtained with the preceding effect of maize + cowpea. The highest pooled system productivity as maize equivalent yield (14 136 kg/ha) was obtained with maize + cowpea treatment which remained at par with application of atrazine or metribuzin as PE plus one HW. Significantly highest pooled gross (₹ 153 864/ha), net (₹ 101 948/ha) returns and B:C ratio (1.96) were also obtained with maize + cowpea, which remained at par with other tested weed management practices. The results indicate that inclusion of cowpea as cover crop in maize-wheat system will not only increase the profitability but also provide environment friendly option against the use of herbicides for weed management.

Key words: Economics, Herbicide, Maize + cowpea, System productivity, Weed dynamics, Weed index

Maize (*Zea mays* L.) is one of the major cereal crops with wide adaptability under diverse agro-climatic conditions around the world. It is the third most important crop of India after rice and wheat that occupied 8.67 m ha area with an average productivity of 2.57 tonnes/ha compared to world average of 4.94 tonnes/ha. Major area of maize in India is during *kharif* season in which weed is one the most important yield limiting factor and significantly reduces the yield. Even with a light infestation of weeds under ideal situation the weeds should be controlled throughout the crop growing season. However, the most critical period for crop weed competition are first six weeks after planting of crop because of initial slow growth and wider row spacing of maize, coupled with congenial weather conditions allow luxuriant weed growth which may reduce yield by 28-100% (Dass *et al.* 2012, Pandey *et al.* 1999). During this critical period weeding is essentially required by chemical or non- chemical means. Weeding by

hands (labour) and mechanical means are expensive and many a times timely operations are not possible due to continuous rains in monsoon season.

Maize is infested by a wide range of weed flora, viz. *Echinochloa colona*, *Cyperus rotundus*, *Commelina benghalensis* and *Trianthema portulacastrum* dominate during early stages of the crop growth whereas *Dactyloctenium aegyptium* toward the tasseling and maturity of the crop (Saini and Angiras 1998). Research and development in herbicide technology has opened up new possibilities for chemical weed management practices. Atrazine has been widely used herbicide for controlling of the weeds in maize but do not provide effective control of many weeds particularly the *Cyperus rotundus* and *Echinochloa colona* (Kandasamy and Chandrasekhar 1998).

Applications of triazine group herbicides have been found effective to reduce the weed intensity and increasing the yield of crop in succeeding season (Kurchania *et al.* 1989). This type of information could be very useful in economizing the herbicides/use in preceding crop (maize) and reducing the weeds growth in succeeding (wheat) crop due to herbicides residues left over and ultimately reducing the pollution hazard. Similarly, the impact of cowpea intercropped with maize on succeeding wheat was also

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found positive (Balyan and Seth 1985). Therefore, the present investigation was under taken to find out promising herbicide combination/alternative for herbicide application to manage all kinds of weed flora in maize and their effects on succeeding wheat crop grown under sequential cropping.

MATERIALS AND METHODS

A field experiment was conducted during the *kharif* and *rabi* seasons of 2010–11 and 2011–12 in maize – wheat (*Triticum aestivum* L.) cropping sequence on the fixed plots at the research farm of the Indian Agricultural Research Institute, New Delhi. It is geographically situated at 28.4° N latitude, 77.1° E longitude and at an altitude of about 228.6 m above mean sea level. It has a semi-arid and sub-tropical climate characterized by hot summer and severe cold winter. The mean maximum temperature was for the month of June which is the hottest month of the year ranges from 40–45°C (Table 1). The mean annual rainfall is about 819 mm of which more than 80% is generally received during the monsoon season (July–September). The soil is of Yamuna alluvium origin and belonging to the order inceptisol. The soil of experimental field was sandy loam in texture and alkaline in nature (pH 7.6), low in organic carbon (0.38%) and medium in available nitrogen (145.4 kg/ha), phosphorus (22.6 kg/ha) and potash (209.4 kg/ha). A set of eight treatments comprising application of atrazine 1.0 kg/ha as pre emergence (PE), metribuzin 0.25 kg/ha as PE, atrazine 1.0 kg/ha as 21 days after sowing (DAS), atrazine 1.0 kg/ha as PE + 1 HW, metribuzin 0.25 kg/ha as PE + 1 HW, maize + cover crop (cowpea) along with weedy check and two hand weeding as weed free were laid out in completely randomized block design with three replications. The seeds of maize single cross hybrids HQPM 1 and DHM 117 were dibbled manually at spacing of 67 cm × 20 cm using 20 kg seed/ha in first week of July during both the years of experimentation (2010 and 2011), respectively and fertilized with 150, 60 and 40 (N, P₂O₅ and K₂O) kg/ha. Both P and K and 1/3 dose of nitrogen were applied at the time of sowing as basal application, whereas the remaining quantity of N was applied in two equal splits at knee high and tasseling stages. All the herbicides were applied using 600 litres of water/ha with the help of knapsack sprayer fitted with flat fan nozzle. The succeeding wheat crop cv HD 2967 was sown on 20 and 11 November and harvested on 2 April and 7 April during both the years of study (2011 and 2012), respectively. The wheat crop was fertilized with 40 kg N, 60 kg P₂O₅ and 40 kg K₂O/ha at sowing as basal and remaining 80 kg nitrogen was top dressed in two equal splits at 30 and 60 DAS. All other practices were followed as per recommendations for both maize and wheat crops. The unwedded control (weedy check) was kept undisturbed for the entire cropping period of the *kharif* maize crop. To see the residual effects of the treatment applied in maize, the wheat crop was raised with recommended weed management practices.

Data pertaining to weed population and dry weight were recorded at harvest in maize from two places in each

Table 1 Mean weekly meteorological data

Month	Standard Week	2010-11		2011-12			
		Rain-fall (mm)	Temperature (°C)		Rain-fall (mm)	Temperature (°C)	
			Maxi-mum	Mini-mum		Maxi-mum	Mini-mum
June	23	0	42.1	26.3	10.4	37.8	26.1
	24	0	40.3	26.0	43.8	36.2	25.4
	25	0	42.3	17.1	44.6	35.7	27.1
	26	4.6	41.8	28.4	1.4	35.1	26.2
July	27	126.8	36.9	25.9	0.2	33.6	26.0
	28	53.4	35.6	27.6	18.2	33.3	25.7
	29	46.8	35.9	27.5	4.9	34.5	26.2
	30	9.8	35.3	26.3	10.5	34.9	26.3
	31	33.8	35.8	27.0	21.0	29.4	26.7
August	32	59.4	37.0	27.8	106.7	31.5	24.8
	33	46	32.9	25.6	105.3	32.8	25.1
	34	192.8	34.8	24.6	37.6	33.1	25.4
	35	6.6	32.6	25.2	71.2	33.7	25.4
Sep-tember	36	62.6	32.7	23.2	52.6	32.2	25.4
	37	109.8	29.6	21.6	41.6	33.3	24.6
	38	96.2	35.2	23.8	0.0	33.8	23.2
	39	45.6	36.0	23.5	0.0	34.5	22.5
October	40	0	32.7	22.8	0.0	33.9	20.3
	41	0	34.6	16.8	0.0	33.9	17.6
	42	0	32.8	15.8	0.0	32.2	15.5
	43	22	31.5	11.6	0.0	30.2	13.7
	44	0	30.5	14.0	0.0	31.1	13.4
November	45	0	27.9	11.2	0.0	29.7	14.2
	46	3.6	26.6	10.3	0.0	28.2	12.4
	47	9	25.8	6.5	0.0	26.4	10.7
	48	0.8	25.3	9.2	0.0	26.3	9.8
December	49	0	20.9	6.1	0.0	24.4	10.4
	50	0	17.7	5.3	0.0	21.2	2.2
	51	0	20.8	3.2	0.0	19.9	1.7
	52	0	19.5	4.9	0.0	20.5	5.7
January	1	0.3	16.7	6.4	6.6	17.4	6.3
	2	0	13.8	6.9	8.2	18.6	5.5
	3	0	17.0	6.8	0.0	18.0	5.1
	4	0	20.7	6.6	0.0	20.4	3.4
February	5	0	23.6	7.2	0.0	21.4	7.1
	6	6.4	24.7	10.9	0.0	21.2	7.9
	7	21.1	22.2	8.2	0.0	24.2	8.8
	8	15.4	25.4	10.3	0.0	24.7	8.4
	9	8.3	30.3	14.5	0.0	29.4	11.8
March	10	2.3	29.1	13.4	19.2	26.2	9.0
	11	0	31.8	13.6	0.0	31.6	14.4
	12	0	36.7	16.6	0.0	32.1	15.8
	13	0	37.5	18.2	0.0	35.6	18.2
April	14	0	33.2	14.3	6.8	36.0	19.3
	15	0	34.1	18.6	0.0	32.6	18.5
	16	2.2	35.5	16.4	2.2	36.4	20.3
	17	0	39.0	22.6	0.0	36.4	18.7
May	18	0	40.5	23.5	0.0	39.5	23.7
	19	0	38.2	21.7	13.6	39.5	22.6
	20	0	39.7	26.6	0.0	41.7	25.2
	21	4.6	38.7	24.3	0.0	43.8	26.2

plot using 50 cm × 50 cm quadrat and counted species-wise. The efficacy of weed management treatment was assessed by weed index which was calculated as:

$$\text{Weed index} = \frac{x - y}{x} \times 100$$

where *x* is grain yield of maize in weed free plots and *y* is the grain yield in the respective treatment.

System productivity in terms of maize equivalent yield was calculated by adding the grain yield of maize with maize equivalent yield of wheat calculated using minimum support price (MSP) offered by CACP, Government of India for both crops in respective years. The cost of cultivation under various treatments was estimated on the basis of prevailing rates for inputs in New Delhi. The input costs included costs of seed, herbicide treatment application, chemical fertilizers, and the hiring charges of human labour and machines for land preparation, irrigation, fertilization, harvesting, and threshing. Gross returns were calculated by multiplying maize equivalent yield of the system with MSP of maize in both the years. The net returns were calculated with respect to each treatment by subtracting the total cost of cultivation from gross returns. The benefit: cost ratios were calculated for each treatments applied in the system as the ratios of net returns to cost of cultivation.

Analysis of variance (ANOVA) was done to determine treatment effects by using SAS 9.3 (SAS Institute, Cary, NC). Tukey's honest significant difference test was used as a post hoc mean separation test (*P* < 0.05).

RESULTS AND DISCUSSION

Effect of different weed control treatments on weed flora

When we analyzed effect of different weed control treatment on weeds population in *kharif* maize field during both the years (Table 2) it was observed that *Dactyloctenium aegyptium* weed was difficult to control by pre-emergence application of either atrazine 1.0 kg/ha or metribuzin 0.25 kg/ha, however it was effectively controlled by pre-emergence application of metribuzin 0.25 kg/ha followed by one hand weeding at 21 DAS. Sharma and Thakur (1998) also reported the poor efficacy of atrazine against many weeds in maize. However, Sharma and Pankaj (2013) reported that the performance of atrazine was found better than pendimethalin in reducing the population of several weed species, viz. *Commelina benghalensis* and *Trianthema portulacastrum* etc. However, *Commelina benghalensis*, *Digera arvensis* and *Leptochloa chinensis* were not controlled by application of atrazine when it was used as post emergence. In contrast to this when atrazine/metribuzin was used as pre emergence most of the broad leaf weeds were controlled (Table 3). Whereas, encouraging results for smothering effect of maize + cowpea were observed on the growth of many weeds as most of these weeds were suppressed by this live mulch treatment. Cowpea had such a large effect on weed suppression due to its ability to develop over-ground runners, which occupied the inter-row spaces and restricted the germination and growth of

Table 2 Effect of chemical and non-chemical weed management practices on weed population at harvest of *kharif* maize (pooled data of two years*)

Treatment	No. of Weeds/0.25 m ²									
	<i>Celosia argentea</i>	<i>Commelina benghalensis</i>	<i>Dactyloctenium aegyptium</i>	<i>Digera arvensis</i>	<i>Eluesine indica</i>	<i>Echinochloa colona</i>	<i>Corchoris trilocularis</i>	<i>Leptochloa chinensis</i>	<i>Rumex acetosella</i>	Total
Atrazine PE	0.71 ^b (0)	2.72 ^a (4.5)	1.59 ^b (2.5)	0.71 ^b (0)	3.01 (11.5)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	11.06 ^{bc}
Metribuzin PE	0.71 ^b (0)	2.62 ^a (6.5)	3.92 ^a (15.0)	0.71 ^b (0)	1.47 (2.0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	1.47 ^a (2.0)	13.02 ^{abc}
Atrazine 21 DAS	0.71 ^b (0)	3.89 ^a (15.0)	3.29 ^{ab} (10.5)	1.17 ^b (1.0)	0.71(0)	0.71 ^b (0)	0.71 ^b (0)	1.59 ^a (2.5)	0.98 ^{ab} (0.5)	13.74 ^{ab}
Atrazine PE + 1 HW	0.71 ^b (0)	2.22 ^a (7.0)	3.27 ^{ab} (11.0)	1.17 ^b (1.0)	1.59 (2.5)	1.59 ^a (2.5)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	14.07 ^{ab}
Metribuzin PE + 1 HW	1.47 ^a (2.0)	3.21 ^a (10.5)	2.42 ^{ab} (7.0)	1.59 ^b (2.5)	2.18 (5.5)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	13.70 ^{ab}
Maize + cowpea	0.71 ^b (0)	4.00 ^a (14.0)	3.96 ^a (15.5)	1.33 ^b (1.5)	1.71 (3.0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	14.23 ^a
Weedy check	0.71 ^b (0)	3.70 ^a (15.5)	2.96 ^{ab} (8.5)	2.92 ^a (8.0)	0.71 (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.98 ^{ab} (0.5)	14.39 ^a
Weed free (2HW)	0.71 ^b (0)	2.49 ^a (7.5)	2.34 ^{ab} (6.5)	0.98 ^b (0.5)	0.71 (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	10.05 ^c
p-Value	0.0238	0.1105	0.0281	0.0005	0.1880	0.0232	0.0232	0.0232	0.0243	0.0014

*The data were transformed before statistical analysis using square root transformation $\sqrt{x+0.5}$. Treatment means following different letters are significantly different at Tukey's HSD at 5%. Figure in parenthesis is the original value for respective data.

Table 3 Effect of chemical and non-chemical weed management practices on weed dry matter accumulation at harvest of *kharif* maize (pooled data of two years*)

Treatment	Weed dry weight (g/0.25 m ²)									
	<i>Celosia argentea</i>	<i>Commelina benghalensis</i>	<i>Dactyloctenium aegyptium</i>	<i>Digera arvensis</i>	<i>Eluesine indica</i>	<i>Echinochloa colona</i>	<i>Corchoris trilocularis</i>	<i>Leptochloa chinensis</i>	<i>Rumex acetosella</i>	Total
Atrazine PE	0.71 ^b (0)	3.01 ^a (6.2)	1.12 ^b (0.9)	0.71 (0)	1.76 (3.2)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^a (0)	9.66 ^{ab}
Metribuzin PE	0.71 ^b (0)	3.15 ^a (9.5)	3.04 ^a (8.8)	0.71 (0)	1.34 (1.5)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	1.23 ^a (1.2)	12.30 ^{ab}
Atrazine 21 DAS	0.71 ^b (0)	3.16 ^a (9.5)	2.33 ^{ab} (5.0)	1.50 (2.1)	0.71 (0)	0.71 ^b (0)	0.71 ^b (0)	0.81 ^a (0.2)	1.05 ^a (0.7)	11.69 ^{ab}
Atrazine PE + 1 HW	0.71 ^b (0)	2.54 ^a (8.7)	1.98 ^{ab} (4.0)	1.48 (2.0)	0.94 (0.4)	1.26 ^a (1.3)	1.02 ^a (0.6)	0.71 ^b (0)	0.71 ^a (0)	11.82 ^{ab}
Metribuzin PE + 1 HW	1.05 ^a (0.7)	3.16 ^a (9.6)	2.02 ^{ab} (4.6)	1.50 (2.1)	1.31 (1.4)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^a (0)	11.88 ^{ab}
Maize + Cowpea	0.71 ^b (0)	3.66 ^a (21.3)	2.64 ^{ab} (6.5)	0.98 (0.5)	1.74 (3.1)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^a (0)	13.33 ^a
Weedy check	0.71 ^b (0)	4.42 ^a (13.4)	2.10 ^{ab} (4.1)	1.72 (2.6)	0.71 (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.86 ^a (0.3)	11.87 ^{ab}
Weed free (2HW)	0.71 ^b (0)	2.65 ^a (8.7)	1.48 ^{ab} (2.0)	0.81 (0.2)	0.71 (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^b (0)	0.71 ^a (0)	9.19 ^b
p-Value	0.0275	0.3969	0.0212	0.0900	0.1975	0.0252	0.0281	0.0331	0.0261	0.0324

*The data were transformed before statistical analysis using square root transformation $\sqrt{x + 0.5}$. Treatment means following different letters are significantly different at Tukey's HSD at 5%. Figure in parenthesis is the original value for respective data.

weeds. In other words, the lack of availability of uncovered inter-row spaces for weed establishment resulted in severe reduction in the weeds biomass. Many previous studies have also confirmed lower dry weight of weeds in a system that uses cover crops by covering the inter-row spaces which ultimately suppresses weed emergence (Teasdale and Mohler 1993).

Effect of weed index

During first year of study significantly lowest weed index was obtained with metribuzin + 1 HW treatment which remained at par with sole application of metribuzin, while in second year of experimentation, significantly lowest weed index was obtained with maize + cowpea intercropping treatment which remained at par with atrazine PE + 1 HW treatment combination (Table 4). The pooled data for weed index also showed that maize + cowpea intercropping resulted lowest weed index which was at par with metribuzin + 1 HW and atrazine PE + 1 HW treatment combination. It clearly shows that maize + cowpea treatment resulted in lower weed index due to smothering effect of cowpea on weed growth. Therefore, it is advisable that maize can be intercropped with short duration legume such as cowpea as living mulches which reduces weed density with little/no effect on maize yield. Living mulches suppress weeds by competing for the use of growth resources, and changing environmental factors that affect weed germination and establishment, and can ultimately result in reduced herbicide application (Liebman and Davis 2000). Cowpea had significant effect on weed suppression due to its ability to develop over-ground foliage, which occupied the inter-row spaces of intercropping treatment and restricted the germination of weed seeds and growth of weeds. Many workers reported lower weeds and their dry weights in various cropping systems by using cover crops because it covers the inter-row spaces and suppresses weed emergence (Teasdale and Mohler 1993).

Grain yield

Maize: During both the years of experimentation (Table 5), it was found that significantly higher maize yield was obtained with 2 HW treatment, however, in first year sole

Table 4 Effect of weed management treatment on weed index of *kharif* maize

Treatment*	2010	2011	Pooled
Atrazine PE	3.90 ^{cd}	16.10 ^b	10.00 ^{ab}
Metribuzin PE	1.30 ^{cd}	12.73 ^b	7.01 ^b
Atrazine 21 DAS	13.87 ^b	15.61 ^b	14.74 ^{ab}
Atrazine PE + 1 HW	3.60 ^{cd}	0.67 ^c	2.13 ^b
Metribuzin PE + 1 HW	0.40 ^d	1.27 ^c	0.83 ^b
Maize + Cowpea	4.00 ^c	0.53 ^c	2.27 ^b
Weedy check	22.30 ^a	31.16 ^a	26.73 ^a
p-Value	<.0001	<.0001	0.0126

*Treatment means following different letters are significantly different at Tukey's HSD at 5% level

Table 5 System productivity and individual crops yield of maize-wheat cropping system (kg/ha) under different weed management practices

Treatment*	Maize		Wheat		System	
	2010	2011	2010-11	2011-12	2010-11	2011-12
Atrazine PE	4373 ^a	7583 ^{ab}	6905 ^{ab}	4395 ^{bcd}	13004 ^a	12606 ^{bc}
Metribuzin PE	4489 ^a	7873 ^a	6441 ^{abc}	4505 ^{abc}	12540 ^a	13022 ^{ab}
Atrazine 21 DAS	3916 ^{ab}	7583 ^{ab}	6603 ^{abc}	4954 ^{ab}	12170 ^{ab}	13246 ^{ab}
Atrazine PE + 1 HW	4388 ^a	8963 ^a	6294 ^{abc}	4395 ^{bcd}	12255 ^{ab}	13986 ^{ab}
Metribuzin PE + 1 HW	4535 ^a	8904 ^a	6200 ^{bc}	4230 ^{cd}	12285 ^{ab}	13739 ^{ab}
Maize + Cowpea	4372 ^a	8971 ^a	7281 ^a	5100 ^a	13473 ^a	14800 ^a
Weedy check	3535 ^b	6208 ^b	5800 ^c	3876 ^d	10785 ^b	10638 ^c
Weed free (2HW)	4550 ^a	9021 ^a	6078 ^{bc}	4346 ^{bcd}	12148 ^{ab}	13989 ^{ab}
p-Value	0.0031	<.0001	0.0005	<.0001	0.0004	<.0001

*Treatment means following different letters are significantly different at Tukey's HSD at 5% level.

application of metribuzin and application of metribuzin + 1 HW remained at par to this, while during second year of study, it was found at par with maize + cover crop cowpea, atrazine PE + 1 HW, metribuzin + 1 HW and metribuzin alone application. During both the years of experimentation, the use of cowpea as live mulch increased the maize yield by 23.7 and 44.5% respectively, over weedy check. Similar findings also reported that cowpea as cover crop can act as live mulch in maize production which reduced weed biomass production and intercropping of maize at a density of 7.5 plants/m² with cowpea at densities of 15 and 30 plants/m² increased maize grain yield by 15.8 and 22.3%, respectively (Jamshidi *et al.* 2013). Maize is characterized as a nitrophilic crop and therefore, the potential biological nitrogen fixing abilities of legume crops such as cowpea would bring further benefits by reducing the amount of N fertilization needed for maize crop. Inclusion of cover crops into weed management strategy for either individual crop or in cropping sequence will be a cost-effective and environmental friendly practice that will also help to save the environment, improve soil fertility and ultimately enhance the crop yield.

Wheat

During first year (2010-11) of experimentation lower *kharif* maize yield was harvested, but high yield of wheat crop ranging from 5 800 kg/ha in weedy check to 7 281 kg/ha in maize + cowpea as cover crop were obtained. However, during second year of experimentation high maize yield in the range of 6 208 kg/ha in weedy check to 9 022 kg/ha in weed free treatment was obtained. Due to this low yield of succeeding wheat was obtained which was in the range of 3 876 kg/ha in weedy check to 5 100 kg/ha in maize + cowpea cover crop. It shows that ability of soil to supply nutrient is limited and the nutrient applied to *kharif* maize have significant residual effect may be either positive or negative on succeeding wheat crop. So, the carrying capacity of soil in both the cases reflected as system productivity

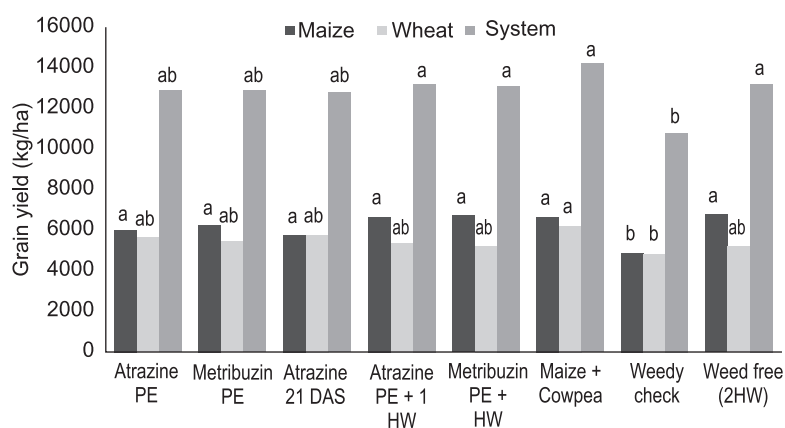


Fig 1 Pooled grain yield of individual crops and system under different weed management practices of maize-wheat system (bars following different letters are significantly different at Tukey's HSD at 5%)

was more than 10 tonnes/ha in any case.

During both the years and on pooled basis significantly higher grain yield of wheat was obtained with maize + cowpea cover crop treatment (Fig 1). The data revealed that this treatment combination increased pooled wheat grain yield by 7.1, 9.6, 13.1, 15.8, 18.7, 18.8 and 27.9% over application of atrazine at 21 DAS, atrazine as PE, metribuzin as PE, atrazine as PE + 1 HW, metribuzin as PE + 1 HW, weed free (2HW) and weedy check, respectively. It shows that the residual effect of cowpea intercrop with maize resulted in potential biological nitrogen fixing abilities of cowpea which brought beneficial effect on realization of wheat yield. Balyan and Seth (1985) also reported the beneficial residual effect of cowpea (fodder) on succeeding wheat crop to the tune of 5.02 tonnes/ha followed by maize + cowpea grain (4.79 tonnes/ha) and the yields of both these treatments were superior to maize alone.

System productivity

During both the years of study the highest system productivity was realized with maize + cowpea treatment. In first year this treatment was statistically at par with PE application of atrazine and metribuzin, however during second year of study it was superior over all other treatment

combinations, suggesting that inclusion of cowpea not only had beneficial effect on maize but it also increased succeeding wheat crop yield and ultimately resulting in significantly higher system productivity. Adigbo *et al.* (2013) also reported that alternate row additive and alternate stand spatial arrangements have the potential to enhance the productivity of two cowpea varieties without reducing maize yield in derived savannah of Nigeria. Nitrogen fixation from legume makes “free” N for use by the host plant or by associated or subsequent crops as legume effect. Replacing it with fertilizer N would cost \$7 to 10 billion annually, whereas even modest use of alfalfa in rotation with corn could save farmers \$200 to 300 million (Peterson and Russelle 1991). The most common goal of intercropping is to produce a higher yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop.

Economics

Economic benefit is the final aim of the any intervention made in the traditional package of practices for raising crops. Gross returns, net returns and B:C ratios were calculated to find out the economic viability of different weed control treatments imposed. The data presented in Table 6 showed that there was wide variation in the net returns and B:C ratio obtained in maize–wheat system due to direct and residual effect of different weed control treatments. Significantly highest gross and net returns of (₹ 153 864 and ₹ 101 948 /ha) was realized from maize + cowpea cover crop treatment in maize-wheat cropping system over control, however, it remained at par with other weed management options studied. Sharma and Pankaj (2013) also found the significant variation in net return and B:C ratio obtained in maize–wheat system due to direct and residual effect of different weed control treatments. Similarly, significantly higher B:C ratio was also obtained with maize + cowpea cover crop treatment, which remained

Table 6 Economics of maize–wheat system under various herbicidal treatments applied in *kharif* maize (pooled data of two years)

Treatment*	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
Atrazine PE	141508 ^{ab}	52070 ^e	89443 ^{ab}	1.72 ^{ab}
Metribuzin PE	141302 ^{ab}	52309 ^d	88997 ^{ab}	1.70 ^{ab}
Atrazine 21 DAS	140946 ^{ab}	52070 ^e	88880 ^{ab}	1.70 ^{ab}
Atrazine PE+1 HW	147098 ^{ab}	53915 ^c	93187 ^{ab}	1.73 ^{ab}
Metribuzin PE+1 HW	142099 ^{ab}	54154 ^b	87950 ^{ab}	1.62 ^{ab}
Maize + Cowpea	153864 ^a	51920 ^f	101948 ^a	1.96 ^a
Weedy check	121963 ^b	51120 ^g	70847 ^b	1.39 ^b
Weed free (2HW)	143596 ^{ab}	54810 ^a	88791 ^{ab}	1.62 ^{ab}
<i>p</i> -Value	0.047	<.0001	0.0584	0.0495

*Treatment means following different letters are significantly different at Tukey’s HSD at 5% level.

at par with other weed control measures that clearly indicating that inclusion of cowpea not only increases economic profit but also providing environment friendly option against use of chemical herbicides.

On the basis of cost: benefit ratio it can be concluded that inclusion of cowpea not only increases the profit but also provide an environment friendly option against use of chemical herbicides by competing for the use of growth resources, and changing environmental factors that affect weed germination and establishment, and can ultimately result in lesser herbicide application.

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