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Competitive ability of intercrops and herbicides for controlling weeds in maize (*Zea mays* L.)

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ABSTRACT : A field experiment was conducted in the sandy loam soil of Kanke, Ranchi during *Kharif* seasons of 2004 and 2005, to find out most effective combinations of intercrops and herbicides for controlling weeds in *Kharif* maize. The experiment was laid out in Split Plot Design comprising five cropping systems, *i.e.*, sole maize, sole soybean, sole groundnut, intercropping of maize+soybean (1:2) and intercropping of maize+groundnut (1:2) as main plots and five weed management practices, *i.e.*, weedy check, weeding thrice at 15, 30 and 45 days after sowing, oxyfluorfen @ 0.2 kg a.i. ha^{-1} as pre-emergence, alachlor @ 2.0 kg a.i. ha^{-1} as pre-emergence and butachlor @ 1.5 kg a.i. ha^{-1} as pre-emergence + quizalofop-ethyl @ 100 ml ha^{-1} as post emergence, as sub plot treatments, replicated thrice. The result showed that maize intercropped with soybean and hand weeded thrice has lowest weed density and weed dry weight, which were statistically at par with that of maize intercropped with soybean and sprayed with oxyfluorfen @ 0.2 kg a.i. ha^{-1} as pre-emergence. The highest maize equivalent yield of 8039 kg ha^{-1} was recorded with maize+groundnut and hand weeded thrice, which was found to be statistically at par with maize+groundnut, treated with oxyfluorfen @ 0.2 kg a.i. ha^{-1} as pre-emergence and maize+soybean, treated with oxyfluorfen @ 0.2 kg a.i. ha^{-1} as pre-emergence, having maize equivalent yields of 7595 kg ha^{-1} and 7189 kg ha^{-1}, respectively. The highest net return was recorded from the intercropping of maize+groundnut, treated with oxyfluorfen @ 0.2 kg a.i. ha^{-1} as pre-emergence, which can be used as the most effective and profitable combination in controlling weeds in *Kharif* maize.

KEY **W**ORDS : Maize, Soybean, Groundnut, Intercropping, Weed, Oxyfluorfen, Alachlor

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Maize (*Zea mays* L.) is one of the most important cereal of the world and is referred to as the "queen of cereals" primarily because of its very high yield potential, suitability for being cultivated all-round the year and multifaceted uses as food, feed, forage and in processing industry. In India, maize is cultivated in about 9.43 million ha., producing 24.35 million ton of grain, having an average productivity of 25.8 q ha^{-1} (Anonymous, 2014). Though it has the potential of growing both under *Kharif* and *Rabi* season, the yield during *Kharif* season is much lower than those during winter and summer seasons. The reason for this low yield during *Kharif* season is mainly due to infestation of weeds and their luxuriant growth. Maize, being a wide spaced row crop

and having a slow growth rate, especially in its early growth stages, offers ample opportunity for emergence and growth of weeds. These weeds give serious competition to the crop, competing for nutrients, moisture and light, resulting their poor growth and development, which ultimately referred to low yields (Porwal, 1993). Of the total estimated losses caused in production by insects, diseases and weeds in the world, weeds alone are responsible for one third of it. (Saraswat *et al*.,2003). Maize, being a rainy season and widely spaced crop, gets infested with variety of weeds and subjected to heavy weed competition, which often inflicts huge losses ranging from 28 to 100 per cent (Patel *et al.*, 2006). Thus, it is very essential to control the infestation of weeds so as to enhance the yield of maize during rainy season. The high cost involved in manual weeding, dearth of labourers, when really are on demand and non-workable condition of the soil due to incessant rains makes it imperative to opt for herbicidal control. The concept of intercropping also offers ample scope for combating weeds without any threat to ecological degradation (Willey, 1979), which can be used for decreasing the dependency on chemical herbicides in weed control (Banik *et al.*, 2006) Intercropping especially cereal + legume combination can increase production and productivity by better utilization of resources and thereby minimizes the risks and brings stability under rainfed conditions (Chatterjee and Mandal, 1992). Intercropping maize and legumes considerably reduced the weed density compared with the monocropping maize by decrease in available light for weeds compared to mono crops (Bilalis *et al.*, 2010). Even if some weeds emerges in spite of growing intercrops, the quantum and frequency of herbicide used will be much lower than those recommended in their crops of pure stand. With these views under considerations, the present investigation was carried out with the objectives to find out the most effective intercropping system and herbicides for control of weeds in maize.

RESEARCH PROCEDURE

A field experiment on weed management in maize based intercropping system was conducted under during *Kharif* season of 2004 and 2005 at the research farm of Birsa Agricultural University, Kanke, Ranchi, which is situated at a latitude of 23^0 17' N and longitude 85^0 19' E, with an altitude of 625.22 m above the mean sea level, in the Chotanagpur plateau of Jharkhand state, under agroclimatic zone VII (Eastern plateau and hill region) of India. The average annual rainfall of this locality is around 1400 mm of which 80-85 per cent is received during four monsoon months, June to September. The total rainfall received from July to October was 889.3 and 934.9 mm in 2004 and 2005, respectively. The maximum and minimum temperature correspondingly ranged from 25.6 to 33.7^0C and 9.8 to 24.0^0C in 2004 and from 25.2 to 31.9^0C and 9.8 to 23.3^0C, respectively in 2005. The relative humidity during the crop season in both the years remained close to the normal. The experimental field represents upland having ultipale ustalf red sandy loam type of soil with pH 5.9, organic carbon 0.52 per cent, available N 261.6 Kg ha^{-1}, available P_2O_5 21.5 kg ha^{-1} and available K_2O 195 kg ha^{-1}.

The experiment was laid out in Split Plot Design, comprising five cropping systems as main plot treatment and five weed management practices as sub plot treatments with three replications. The five main plot treatments were sole maize at 75 cm apart (C_1), sole soybean at 30 cm apart (C_2), sole groundnut at 30 cm apart (C_3), maize+soybean (1:2) (C_4) and maize+ groundnut (1:2) (C_5). The sub plot treatments include weedy check (W_1), weeding thrice at 15, 30 and 45 days after sowing (W_2), oxyfluorfen @ 0.2 kg a.i. ha^{-1} as pre-emergence (W_3), alachlor @ 2.0 kg a.i. ha^{-1} as pre-emergence (W_4) and butachlor @ 1.5 kg a.i. ha^{-1} as pre-emergence + quizalofop-ethyl @ 100 ml ha^{-1} as post emergence (W_5). The variety taken for maize, soybean and groundnut were Suwan composite, Bragg and AK 12-24, respectively. The crop was sown in the first fortnight of July and harvested in the second fortnight of October of both the years. The recommended nutrient doses of 100:60:40 N:P_2O_5:K_2O kg ha^{-1} for maize, 30:60:40 N:P_2O_5:K_2O kg ha^{-1} for soybean and 30:60:30 N: P_2O_5: K_2O kg ha^{-1} for groundnut were applied. All the agronomic and plant protection management practices were undertaken for successful experimentation. The herbicides were applied with their respective doses as per treatments. Spraying was done with flat fan nozzle with knapsack sprayer by taking 500 l. of water per ha. Weed population and weed dry weight were taken using quadrate of 1m x 1m at 30, 60 and 90 DAS. Weed data were subjected to square root transformation before statistical analysis. The weed control efficiency (WCE) of each treatment was computed by the formula given below:

$$\text{WCE (\%)} = \frac{\text{WDC} - \text{WDT}}{\text{WDC}} \times 100$$

where,

WCE = Weed control efficiency

WDC= Dry matter accumulation by weeds in unweeded plot (g m^{-2})

WDT= Dry matter accumulation by weeds in treated plots (g m^{-2})

The yield attributes, yield and economics of crops and intercrops were recorded after harvest of the crop. The economics performance of the treatments were evaluated in terms of gross return, net profit and benefit cost ratio on the basis of prevailing cost of inputs and market value of the produce. The data thus, obtained were statistically analyzed as per procedure of analysis of variance technique and the significance of different source of variations were tested by error mean square of Fischer's F test at probability level 0.05 (Cochran and Cox, 1977).

RESEARCH ANALYSIS AND REASONING

The findings of the present study as well as relevant discussion have been presented under following heads :

Weed flora :

The most predominant weeds observed in the experimental plots were grasses like *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Echinochloa colonum*, *Echinochloa crusgalli*, *Eleusine indica* and *Panicum repens*, sedges like *Cyperus rotundus* and broadleaved weeds like *Ageratum conyzoides*, *Amaranthus viridis*, *Stellaria media*, *Bidens pilosa* L., *Commelina benghalensis*, *Celosia argentea*., *Euphorbia hirta* and *Phyllanthus niruri*. Among all the weeds, the broad leaved weeds dominated the weed dynamics with highest population of 51.4 per cent, followed by grasses (36.2%) and sedges (12.4%).

Weed count :

The pooled analysis of two years data clearly revealed that among all the weed control treatments, three hand weedings recorded significantly lower weed densities of 13.80, 27.0 and 31.5 m^{-2} at 30, 60 and 90 DAS, respectively, than the rest of the treatments, whereas among the herbicides used, oxyfluorfen @ 0.2 kg a.i. ha^{-1} as pre-emergence application recorded significantly lower weed populations of 17.1, 31.5 and 34.5 m^{-2} followed by the pre-emergence application of alachlor @ 2.0 kg a.i.ha^{-1} at 30, 60 and 90 DAS,

Table 1: Interaction effect of cropping system and weed management on mean weed density

Weed management	30 DAS					60 DAS					90 DAS				
	M	S	G	M+S	M+G	Mean	M	S	G	M+S	M+G	Mean	M	S	G	M+S	M+G	Mean
Weedy check	97.5	82.8	89.0	47.5	55.2	74.4	138.8	127.7	132.9	95.5	110.2	125.0	147.0	137.5	141.5	107.5	121.3	131.0
Weeding thrice	16.7	14.0	16.0	10.2	12.2	13.8	25.6	29.1	29.5	17.5	20.6	27.0	30.8	34.2	40.5	23.8	28.5	31.5
Oxyfluorfen (PE)	20.3	18.3	19.0	13.3	14.0	17.1	28.3	32.2	31.3	21.2	26.5	31.5	34.5	36.7	42.3	27.7	32.3	34.7
Alachlor (PE)	27.8	25.0	25.5	14.1	13.8	21.2	32.8	35.1	34.4	21.9	25.9	32.6	36.5	39.5	42.8	33.8	35.5	37.6
Butachlor (PE) + Quizalofop-ethyl (PoE)	36.6	30.8	31.7	22.4	19.9	28.3	36.0	35.7	39.9	29.2	34.0	37.7	40.4	42.5	46.3	35.0	39.0	40.7
Mean	39.8	34.2	36.2	21.5	23.0		52.3	51.9	53.6	37.1	43.4		57.8	58.1	62.7	45.5	51.3	
	C	W	W at same C		C at same W		C	W	W at same C		C at same W		C	W	W at same C		C at same W	
S.E.±	0.54	0.59		1.36		1.46	1.03	0.85		1.8		2.07	1.05	0.92		2.00		2.26
C.D. (P=0.05)	1.58	1.66		3.84		4.12	3.03	2.4		5.12		5.89	3.09	2.57		5.68		6.41

M: Maize, S: Soybean, G: Groundnut, M+S: Intercropping of maize+soybean, M+G: Intercropping of maize+groundnut, PE: Pre-emergence, PoE: Post-emergence

respectively (Table 1). The interaction effect of cropping system and weed management practices on weed density at different days after sowing were also found to be statistically significant. At 30 DAS, the minimum density of weeds of 10.2 m^{-2} was recorded from the plots where maize was intercropped with soybean, along with hand weeding thrice and it was statistically at par with pre-emergence application of oxyfluorfen (13.3 m^{-2}) and Alachlor (14.1 m^{-2}) and these combinations inturn were statistically at par observed under maize + groundnut intercropping system with the weeding thrice (12.2 m^{-2}), application of alachlor (13.8 m^{-2}) and oxyfluorfen (14.0 m^{-2}).

The similar trend was also observed with respect to weed density as influenced by interaction effect of cropping system and weed management practices at 60 DAS. But at 90 DAS, the performance of weed *i.e.* weeding thrice and pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} under both the intercropping system *i.e.* maize+soybean and maize+groundnut was statistically at par in reducing the weed density and these inturn, were significantly superior to rest of the weed management practices under different cropping systems, in reducing the population of weeds. Similar results were also obtained by Anonymous (2010).

Weed dry matter :

The interaction effect of cropping system and weed management practices on dry matter of weeds at 60 DAS was found to be significant, with the lowest weed dry weight of 9.0 g m^{-2} recorded with maize+soybean intercropping along with weeding thrice and was statistically at par with that recorded under maize+soybean intercropping along with pre-emergence application of oxyfluorfen (9.6 g m^{-2}) and alachlor (10.8 g m^{-2}) and was also statistically at par with the dry weight of weeds recorded from maize+groundnut intercropping with weeding thrice (10.5 g m^{-2}), pre-emergence application of oxyfluorfen (11.5 g m^{-2}) and alachlor (12.5 g m^{-2}), which were significantly superior to the rest of the treatment combinations (Table 2).

Similar trend in dry matter accumulation by weeds was observed at 90 DAS with lowest value recorded under hand weeding thrice followed by pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} and alachlor @ 2.0 kg a.i.ha^{-1} under maize+soybean intercropping system, registering the weed dry weights of 10.3, 10.9 and 11.4 g m^{-2}, respectively. These values were statistically at par with that under maize+groundnut intercropping system with values of 11.5, 11.9 and 12.4 g m^{-2}, respectively, but differed significantly with that under all the sole cropping systems.

Weed control efficiency :

Pooled data on weed control efficiency as influenced by intercropping system revealed that highest weed control efficiencies of 51.2 per cent, 59.5 per cent and 60.1 per cent, respectively at 30, 60 and 90 DAS were recorded under maize+soybean intercropping system, followed by maize+groundnut intercropping system, with values of 46.5 per cent, 53.7 per cent and 56.5 per cent, respectively. Lowest weed control efficiency was recorded under sole maize grown in pure stand at their

Table 2 : Interaction effect of cropping system and weed management on dry weight of weeds

Weed management	60 DAS							90 DAS						
	M	S	G	M+S	M+G	Mean	WCE (%)	M	S	G	M+S	M+G	Mean	WCE (%)
Weedy check	42.7	35.5	34.2	28.0	30.5	34.2	-	46.5	39.0	40.5	31.3	33.2	38.1	-
Weeding thrice	15.5	13.9	14.8	9.0	10.5	12.7	62.9	17.8	16.9	18.1	10.3	11.5	14.9	61.0
Oxyfluorfen (PE)	16.4	15.1	15.7	9.6	11.5	13.7	60.3	18.5	16.9	18.7	10.9	12.0	15.4	59.8
Alachlor (PE)	17.3	17.2	16.8	10.8	12.5	14.9	56.7	19.5	17.7	20.0	11.4	12.4	16.2	57.7
Butachlor (PE) + Quizalofop-ethyl (PoE)	19.3	19.1	18.9	12.1	14.0	16.7	51.5	20.4	19.4	21.3	12.2	14.0	17.4	54.4
Mean	22.2	20.2	20.0	13.9	15.8			30.6	27.5	29.6	19.0	20.8		
WCE (%)	35.3	41.2	41.5	59.5	54.0			35.8	42.4	37.9	61.1	56.5		
	C	W	W at same C		C at same W			C	W	W at same C		C at same W		
S.E.±	0.53	0.27	0.6		0.8			0.65	0.27	0.58		0.88		
C.D. (P=0.05)	2.11	0.75	2.01		2.67			2.56	0.78	2.02		3.01		

M: Sole maize, S: Sole soybean, G: Sole groundnut, M+S: Intercropping of maize+soybean, M+G: Intercropping of maize+groundnut

respective growth stages. The high weed control efficiency under intercropping systems might be due to poor weed growth, as reflected in lower weed index value recorded under intercropping system. These findings are in conformity with those reported by Haque *et al.* (2008) and Tripathi *et al.* (2008).

Markable decrease in weed density and weed dry matter production due to weeding thrice and application of herbicides might be probably due to better weed control in critical stages of crop growth through hand weeding and phytotoxic effect of chemicals on broad spectrum of weeds resulting in death of most of the weeds. The herbicides gave almost season-long control of weeds obviously due to their persistence in soil for a sufficiently long time. The results are in conformity with those reported by Yaduraju *et al.* (1986) and Prasad and Srivastava (1990).

Yield attributes of crops :

Data on yield attributes of sole and intercrops in maize based cropping systems as influenced by intercrops and herbicides revealed that maximum values of yield attributes were recorded where the respective crop was grown as sole crop. In contrast to this, the yield attributes of the component crops get significantly influenced due to different herbicidal treatments (Table 3).

Maize :

Pooled data for the herbicidal treatments showed highest values of numbers of cobs plant^{-1} (1.47), number of grain rows cob^{-1} (17.27), numbers of grains row^{-1} (28.54) and 100 seed weight (35.67 g) in the treatment receiving three hand weedings. Application of oxyflurofen @ 0.2 kg a.i ha^{-1} as pre-emergence recorded statistically at par values of yield attributes of maize with 1.4 cobs plant^{-1}, 16.61 grain rows cob^{-1}, 27.52 grains row^{-1} and 35.25 g of 100 seed weight, with the treatment receiving three hand weedings.

Soybean :

Pooled data of the herbicidal treatments showed highest values of number of pods plant^{-1} of 44.5, number of seeds pod^{-1} 3.07 and 100 seed weight of 14.79 g, in the treatment receiving three hand weedings, which was found at par with the application of oxyflurofen @ 0.2 kg a.i ha^{-1} as pre-emergence with values of 42.5 pods plant^{-1}, 2.97 seeds pod^{-1}, and 14.47 g 100 seed weight.

Groundnut :

Pooled data of the herbicidal treatments showed

Table 3: Comparative yield attributes of sole and intercrops in maize based cropping systems as influenced by herbicides

Treatments	Maize				Soybean			Groundnut		
	Cobs plant^{-1}	Grain row cob^{-1}	Grain row^{-1}	100 grain weight (g)	Pods plant^{-1}	Seeds pod^{-1}	100 grain weight (g)	Effective pods plant^{-1}	Kernels pod^{-1}	100 kernel weight (g)
Cropping system										
Maize sole	1.36	15.66	26.99	34.42	-	-	-	-	-	-
Soybean sole	-	-	-	-	33.53	2.78	14.19	-	-	-
Groundnut sole	-	-	-	-	-	-	-	18.35	2.14	31.72
Maize + soybean (1:2)	1.36	15.33	26.76	34.12	33.33	2.87	13.34	-	-	-
Maize + groundnut (1:2)	1.32	15.16	26.28	34	-	-	-	18.45	2.29	31.37
S.E.±	0.011	0.18	0.3	0.14	0.63	0.03	0.29	0.37	0.05	0.15
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management										
Weedy check	1.1	13.05	23.71	31.63	14.33	2.52	12.46	13.03	1.73	25.83
Weeding thrice	1.47	17.27	28.54	35.67	44.5	3.07	14.79	22.69	2.55	34.33
Oxyfluorfen (PE)	1.4	16.61	27.52	35.25	42.5	2.97	14.47	20.75	2.49	33.33
Alachlor (PE)	1.4	15.5	26.98	34.45	38.08	2.8	13.6	19.45	2.31	32.66
Butachlor (PE) + Quizalofop-ethyl (PoE)	1.37	14.5	25.15	32.32	27.47	2.75	13.51	16.1	2.06	31.52
S.E.±	0.02	0.34	0.35	0.23	0.85	0.05	0.24	0.4	0.07	0.38
C.D. (P=0.05)	0.07	0.97	1.12	0.83	2.43	0.14	0.7	1.5	0.29	1.09

NS=Non-significant

highest values of effective pods plant^{-1} (22.69), which was significantly higher than all other weed control treatments. The highest numbers of kernels pod^{-1} (2.55) and 100 kernel weight (34.33 g) were recorded in the treatment receiving three hand weedings, but was found to be at par with the application of oxyflurofen and alachlor as pre-emergence at the rate of 0.2 kg a.i ha^{-1} and 2.0 kg a.i ha^{-1}with values of 2.49 and 2.31 numbers of kernels pod^{-1} and 33.33 and 32.66 g of 100 kernel weight, respectively. The decreasing trend of growth and yield attributing characters of sole crop under intercropping systems may be attributed to comparatively less competition for light, nutrients, moisture and space under sole cropping as compared to intercropping situations. Similar observations were made by Kumar *et al.* (2003) and Pandey *et al*. (2003).

Competitive ability of sole and intercrops :

Land equivalent ratio :

The pooled data revealed that the intercropping systems increased the land equivalent ratio, with higher value of 1.71 recorded under maize+soybean intercropping system, followed by maize+groundnut intercropping with values of 1.70. All the weed management treatment increased land utilization over weedy check. Weeding thrice and pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} recorded the maximum land equivalent ratio of 1.73 each, closely followed by pre-emergence application of alachlor @ 2.0 kg a.i.ha^{-1} (1.70) and combined application of butachlor @ as pre-emergence + quizalofop-ethyl as post-emergence application (1.69) (Table 4).

Competitive ratio :

Pooled data of competitive ration indicated that the intercropping system influenced the competitive ratio with higher value of 2.54 under maize+soybean intercropping system, compared to maize+groundnut intercropping system. Pre-emergence application of oxyfluorfen @ 0.2 kg ha^{-1} recorded higher value of competitive ratio of 2.47, followed by weeding thrice (2.37) and butachlor @ as pre-emergence + quizalofop-ethyl as post-emergence application (2.35).

Aggressivity :

In maize+soybean intercropping system, the higher positive value of aggressively (0.58) indicated that maize crop was more dominant over the soybean, while maize+groundnut intercropping system recorded comparatively lesser value of aggressivity (0.45), thereby indicating that maize was less dominant over groundnut compared to soybean.

Table 4: Land equivalent ratio, competitive ratio, aggressivity and competition index and grain yield as influenced by cropping system and weed management

Treatments	Land equivalent ratio	Competitive ratio	Aggressivity	Competition index	Grain yield (kg ha^{-1})		
					Maize	Soybean	Groundnut
Cropping system							
Maize sole	1.0	-	-	-	3605	-	-
Soybean sole	1.0	-	-	-	-	2389	-
Groundnut sole	1.0	-	-	-	-	-	1902
Maize + soybean (1:2)	1.71	2.54	0.58	0.006	3466	1800	-
Maize + groundnut (1:2)	1.70	2.13	0.45	0.061	3205	-	1546
S.E.±					60.33	36.66	19.00
C.D. (P=0.05)					190.12	100.81	68.74
Weed management							
Weedy check	1.66	2.29	0.5	0.014	2105	1610	1255
Weeding thrice	1.73	2.37	0.54	0.005	4036	2472	2083
Oxyfluorfen (PE)	1.73	2.42	0.54	0.005	3933	2341	1980
Alachlor (PE)	1.70	2.27	0.5	0.007	3766	2189	1839
Butachlor (PE) + Quizalofop-ethyl (PoE)	1.69	2.35	0.52	0.01	3286	1858	1463
S.E.±					88.50	50.22	50.00
C.D. (P=0.05)					251.00	144.00	143.00

Among the weed control treatments, weedy check recorded the minimum value of aggressivity (0.50) indicating that dominancy of component crops could be minimized by suitable intercropping system and weed control measures and the cropping system may be made more remunerative.

Competition index :

Maize+soybean intercropping system recorded the lowest value of competition index (0.006), compared to maize+groundnut intercropping system (0.061), there by indicating that maize+soybean intercropping system was comparatively more beneficial than maize+groundnut intercropping system.Among the different weed control treatments, weeding thrice and pre-emergence application of oxyfluorfen @ 0.2 kg a.i. ha^{-1} recorded minimum competition index of 0.005 each, followed by alachlor @ 2.0 kg a.i. ha as pre-emergence with that of 0.007.

Grain yield of crops:

Maize :

Pooled analysis of both the years revealed significant variations in grain yield of maize due to different cropping system with the highest grain yield of 3605 kg ha^{-1} obtained from pure stand of maize, which inturn, was statistically at par with the grain yield of 3466 kg ha^{-1} recorded from maize+soybean intercropping system but was significantly superior to that of maize+groundnut intercropping system (3205 kg ha^{-1}).

All the weed management practices significantly enhanced the grain yield of maize as compared to weedy check, with maximum grain yield of maize (4036 kg ha^{-1}) recorded from hand weeding thrice and was statistically at par with oxyfluorfen @ 0.2 kg a.i.ha^{-1}, as pre-emergence, with an yield of 3933 kg ha^{-1}, which inturn was significantly superior to the rest of the weed control treatments. Similar result of higher grain yield of maize by oxyfluorfen was reported by Nadiger *et al*. (2013).

The pre-emergence application of alachlor @ 2.0 kg a.i.ha^{-1} with grain yield of 3766 kg ha^{-1} was found to be statistically at par with that under pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1}. Among the herbicides used, combined application of butachlor @ 1.5 kg a.i.ha^{-1}, as pre-emergence along with quizalofop-ethyl @ 100 ml ha^{-1}, as post emergence application proved inferior to the rest of the herbicides in respect of grain yield of maize (3286 kg ha^{-1}).

Soybean :

Cropping system significantly influenced the grain yield of soybean with highest yield of 2389 kg ha^{-1} recorded under sole soybean which was significantly superior to the grain yield obtained under maize+soybean intercropping system (1800 kg ha^{-1}). Among the weed management treatments, the highest grain yield of soybean of 2472 kg ha^{-1} was recorded under hand weeding thrice, being statically at par with the grain yield of 2341 kg ha^{-1}, obtained from the pre-emergence application of oxyfluorfen, which in turn was significantly superior to the grain yield obtained under rest of the weed control treatments.

Groundnut :

Cropping system significantly influenced the yield

Table 5: Effect of cropping system and weed management on maize equivalent yield

Weed management	Cropping system					
	Sole maize	Sole soybean	Sole groundnut	Maize + soybean	Maize + groundnut	Mean
Weedy check	2261	2950	2994	4311	4478	3397
Weeding thrice	4183	4561	4967	7489	8039	5847
Oxyfluorfen (PE)	4111	4294	4828	7189	7595	5603
Alachlor (PE)	3955	3983	4400	6817	7245	5281
Butachlor (PE) + Quizalofop-ethyl (PoE)	3511	3394	3728	5917	5689	4447
Mean	3605	3836	4183	6344	6608	4917
		S.E.±			C.D. (P=0.05)	
C		161.17			456.00	
W		76.50			215.00	
W at same C		159.17			484.00	
C at same W		197.07			599.00	

of groundnut with highest pod yield of 1902 kg ha^{-1} found under sole groundnut and was significantly superior to that under maize+groundnut intercropping (1546 kg ha^{-1}). All the weed management treatments significantly increased the pod yield of groundnut over the weedy check. However, plots weeded thrice produced maximum pod yield of groundnut (2083 kg ha^{-1}), being statistically at par with the pod yield obtained under pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} (1980 kg ha^{-1}) and inturn was significantly superior to the pod yield obtained under rest of the weed management treatments. It was also observed that the performance of pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} and alachlor @ 2.0 kg a.i.ha^{-1} were equally effective in recording the pod yield of groundnut. However, the performance of pre-emergence application of butachlor + post-emergence application of quizalofop-ethyl was inferior to the rest of the chemical weed control methods. The plots without having any weed management practices recorded the lowest pod yield of groundnut (1255 kg ha^{-1}).

Maize equivalent yield of crop :

The maize equivalent yield was significantly influenced by cropping system with the highest value of 6608 kg ha^{-1}, obtained under maize+groundnut intercropping system, which was statistically at par with the equivalent yield (6344 kg ha^{-1}) under maize+soybean intercropping system and inturn, both the intercropping systems proved significantly superior to sole cropping of either of crops. Among the sole crops, groundnut gave significantly higher maize equivalent yield (4183 kg ha^{-1}), being statistically at par with sole soybean, with value of 3836 kg ha^{-1} (Table 5).

Among the weed control treatments, plots weeded thrice produced the highest maize equivalent yield (5847 kg ha^{-1}) which was found at par with pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} (5602 kg ha^{-1}) and was inturn significantly superior to that recorded under rest of the weed control treatments. The interaction effect showed highest maize equivalent yield (8039 kg ha^{-1}) obtained under maize+groundnut intercropping system which was statistically at par with that of maize+soybean intercropping system (7489 kg ha^{-1}) from the plots which were kept almost weed free situation.

The probable reason for higher yields under hand weeding thrice and use of herbicide oxyfluorfen might be due to better weed suppression reducing crop-weed competition at critical growth stages of crops upto minimum level. The results are in conformity with the findings of Sumathi *et al.* (2000) and Gurjar *et al.* (2001).

Economics of crops as influenced by intercrop and herbicides :

Net return :

Cropping system significantly influenced the net

Table 6: Gross return, net return and benefit cost ratio as influenced by cropping system and weed management

Treatments	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit: cost ratio
Cropping system			
Sole maize	21649.6	9568.00	1.78
Sole soybean	19128.4	7405.80	1.64
Sole groundnut	20922.0	9333.20	1.81
Maize+soybean (1:2)	35189.6	20180.30	2.34
Maize+groundnut (1:2)	36277.6	21360.00	2.43
S.E.±	-	304.34	0.04
C.D. (P=0.05)	-	992.36	0.12
Weed management			
Weedy check	18362.4	7713.00	1.66
Weeding thrice	31538.6	15790.00	1.96
Oxyfluorfen (PE)	30317.4	17862.40	2.38
Alachlor (PE)	28637.2	16469.60	2.29
Butachlor (PE) + Quizalofop-ethyl (PoE)	24311.6	10013.20	1.69
S.E.±	-	266.99	0.03
C.D. (P=0.05)	-	763.00	0.09

return with highest value of Rs. 21,360 ha^{-1} recorded from maize+groundnut intercropping system and was statistically at par with that obtained under maize+soybean intercropping system (Rs.20,180.60 ha^{-1}), but was significantly superior to the rest of the cropping systems. Among weed management treatments, pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} recorded the highest net return of Rs. 17,862 ha^{-1} and was significantly superior to the rest of the weed control treatments. The significantly lowest mean value of net return was given by weedy check (Rs.7713 ha^{-1}) (Table 6). The results are in agreement with the findings of Singh and Singh 2001 and Kumar *et al.* (2005).

Benefit: cost ratio :

Among cropping systems, maize+groundnut intercropping recorded highest benefit:cost ratio (2.43) and was statistically at par with that obtained under maize+soybean intercropping system (2.34). Among sole croppings, groundnut recorded higher benefit:cost ratio (1.81) closely followed by sole maize (1.78) and was statistically at par with soybean. Among the weed management practices, pre-emergence application of oxyfluorfen @ 0.2 kg a.i.ha^{-1} recorded maximum benefit:cost ratio (2.38) and was statistically at par with pre-emergence application of alachlor (2.29). The results corroborate the findings of Mandal *et al.* (2004).

Conclusion :

It is clearly revealed from the investigation that intercropping of maize either with soybean or groundnut (1:2) markedly reduced the weed density and dry weight, thereby increasing weed control efficiency, but these could not affect the growth and yield attributes of the component crops, whereas both significantly increased the maize equivalent yield and net return, with highest values under maize+groundnut intercropping system, followed by maize+soybean intercropping system.

Similarly, manual hand weeding thrice at 15, 30 and 45 DAS markedly reduced the weed density and dry weight of weeds, but both manual weeding and pre-emergence application of oxyfluorfen @ 0.2 kg a.i. ha^{-1} proved equally effective in increasing growth parameters, yield attributes and yield, but pre-emergence application of oxyfluorfen @ 0.2 kg a.i. ha^{-1} was found to be the most economically suitable and remunerative in enhancing the yield, thereby increasing the net return substantially.

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