Indian Journal of Agricultural Sciences **88** (7): 1123–8, July 2018/Article

Bio-efficacy of new herbicides on weed dynamics, productivity and nutrient uptake in maize (*Zea mays*) under rainfed condition of Jhabua hills

RAKESH KUMAR YADAV[1], NARENDRA KUMAWAT[2], A SINGH[3], I S TOMAR[4], MAHENDER SINGH[5], JAGDEESH MORYA[6], RAKESH KUMAR[7] and PRAVIN KUMAR UPADHYAY[8]

Zonal Agricultural Research Station, Jhabua, Madhya Pradesh 457 661

Received: 26 March 2018; Accepted: 20 April 2018

ABSTRACT

Field studies were conducted during the rainy seasons of 2014 and 2015 at Zonal Agricultural Research Station, Jhabua under the rainfed condition to determine the effect of new herbicides on weed dynamic, yield and nutrient uptake in maize (*Zea mays* L.). Results revealed that application of saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750 g/ha) recorded the lowest weed density of sedges, grasses and broad leaf weeds in maize, and improved growth, yield attributes and yield of maize. The highest grain yield (3.37 t/ha), stover yield (4.17 t/ha) and biological yield (7.57 t/ha) was recorded with saflufenacil 68 g/l+diamethanamid-P 600 g/l EC (85 +750 g/ha). This treatment also recorded the higher NPK content (1.53, 0.24, 0.34% and 1.01, 0.13, 1.36%, respectively) and uptake (52.06, 8.13, 11.40 kg/ha and 42.08, 5.46, 56.66 kg/ha, respectively) by grain as well as stover. The maximum gross returns (₹ 52 525/ha), net returns (₹ 36 125/ha), B: C ratio (2.20), production efficiency (26.98 kg/ha/day) and economic efficiency (₹ 286.70/ha/day) were recorded under saflufenacil 68 g/l+diamethanamid-P 600 g/l EC (85 +750 g/ha). Hence, for better control of weeds, higher productivity and profitability of maize, herbicide mixture, i.e. saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750 g/ha) should be applied as pre-emergence under rainfed condition of Jhabua hills of Madhya Pradesh.

Key words: CRI, HEI, Maize, Nutrient uptake, Weed control efficiency, Yields

Maize (*Zea mays* L.) is the world's 3rd major cereal crop after wheat and rice (Shivran *et al*. 2013). It is grown for grain as well as green and dry fodder (Neupane *et al*. 2011a,b,c, Kumar and Bohra 2014,). In India maize is cultivated in 6.29 million ha area with the production of 10.30 million tonnes and average productivity of 1.64 t/ha (Kumar *et al*. 2015). In Madhya Pradesh, crop is cultivated in an area of 7.52 lakh ha with the production and productivity of 35.25 lakh tonnes and 4.69 t/ha, respectively (Anonymous 2014).

Weed infestation is one of the major problems in the successful cultivation of maize. Extent of yield losses due to weed competition varies from 28 to 100 % (Patel *et al*. 2006). Thus, to realize the optimum yields weed management is considered very critical (Kumar *et al*. 2017). During the rainy season manual weed control is difficult to adopt due to moist field conditions and scarcity of labour. Hence, chemical weed control is more feasible, less laborious, cost effective and economical in maize (Mandal *et al.* 2011, Sarkar *et al*. 2016). Pre-emergence application of herbicides will control the weeds up to initial 25 days and there after post-emergence application is given, so that further growth of weeds can also be controlled. The new herbicide molecules, i.e. saflufenacil applied either as pre-emergence or in combination with acetochlor, provides good control of grasses as well as broad-leaved weeds (Trolove *et al*.2011). The saflufenacil belongs to pyrimidinedione chemical class and acts by inhibiting enzyme proto-porphyrinogen IX oxidase (PPO), which in turn prevents chlorophyll biosynthesis. Its translocation is predominantly *via* xylem and selectivity is conferred *via* both physical placement and plant tolerance (Grossmann *et al*. 2010). There is limited information on effectiveness of relatively new herbicides including saflufenacil, dimethenamid-P, combination of saflufenacil + dimethenamid-P and its different doses for controlling of weeds in maize. Therefore, the present investigation was carried out with the objectives to find out suitable doses of new herbicides under rainfed condition of Jhabua hills of Madhya Pradesh.

[1]Scientist (e mail: rkyadavrca@rediffmail.com), Krishi Vigyan Kendra, Jhabua 457 661. [2](e mail: kumawatandy@gmail.com), Zonal Agricultural Research Station, Jhabua 457 661. [3]Krishi Vigyan Kendra, Sidhi (MP), [7]Scientitist (e mail: rakeshbhu08@gmail.com), Division of Crop Research, ICAR Research Complex for Eastern Region Patna 800 014. [8]Scientist (e mail: pravin.ndu@gmail.com), Division of Agronomy, Indian Agricultural Research Institutes, New Delhi 110 012.

MATERIALS AND METHODS

Field experiment was conducted during rainy seasons of 2014 and 2015 at Research Farm, Zonal Agricultural Research Station, Jhabua (Latitude 21°30'–22°55'N, longitude 73°30'–75° 01'E; altitude 428 m above mean sea level), Madhya Pradesh. The experimental site was characterized by erratic and uneven rainfall pattern that peaks in June to September. The soil of the experimental site was sandy with shallow to medium depth, low water holding capacity, low in organic carbon (0.39%), available N (210 kg/ha), medium in available P_2O_5 (11.8 kg/ha) and available K_2O (112.2 kg/ha) with pH of 7.3. The total rainfall received during June to December for 2014 and 2015 was 757.6 and 632.2 mm, respectively. The treatments consisting of saflufenacil 68 g/l+dimethanamid-P 600 g/l EC (integrity 668 g/l EC) @ 51+450 g/ha (T1), saflufenacil 68 g/l+dimethanamid-P 600 g/l EC (integrity 668 g/l EC) @ 68+600 g/ha (T_2), saflufenacil 68 g/l+dimethanamid-P 600 g/l EC (integrity 668 g/l EC) @ 85+750 g/ha (T3), alone application of saflufenacil 70% WG (70 g/ha) (T4), dimethanamid-P 600 g/l (600 ml/ha) (T5) and atrazine (500 g/ha) (T6), along with weed free (T7) and weedy (T8) checks, were laid out in a randomized block design with three replications. Maize variety JVM-421 was grown on 19th and 20thJuly at 60 × 25 cm apart during both the years. The harvesting was done on 25 and 29 November 2014 and 2015, respectively. Recommended dose of fertilizers for maize was 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. Total quantity of phosphorus and potassium was applied through single super phosphate and muriate of potash, respectively at sowing. Nitrogen was applied in three splits (50% as basal, 25% at 30 DAS and 25% at 45 DAS) in the form of urea. Calibrated quantity of herbicides was applied as aqueous spray (500 l/ha) with a manually operated knap-sack sprayer fitted with flat-fan nozzle. Pre-emergence application of herbicide was done within 24 hours of sowing. Data on weeds were recorded per plot at 30, 45 and 60 DAS using a quadrate of 0.25 m^2. Grain and stover yields under various treatments were recorded separately and analyzed statistically. The NPK contents in grain and stover were determined as per standard procedures. The uptake of NPK at harvest in grain and stover was estimated by using the following formula:

$$\text{Total uptake (kg/ha)} = \frac{\text{Nutrient concentration (\%) in grain} \times \text{grain yield (kg/ha)} + \text{Nutrient concentration (\%) in straw} \times \text{straw yield (kg/ha)}}{100}$$

Herbicide efficiency index (HEI) was computed using following formula (Krishnamurthy *et al*. 1975):

$$\text{Herbicide efficiency index} = \frac{\text{Yield in treated plot} - \text{yield in control plot}}{\text{Yield in treated plot}} \times 100$$

Crop resistance index (CRI) gives relationship between a proportionate increase in crop biomass and proportionate decrease in weed biomass in treated plots. It was calculated as suggested by Mishra and Misra (1997).

$$\text{Crop resistance index} = \frac{\text{Crop dry weight in treated plot}}{\text{Crop dry weight in control plot}} \times \frac{\text{Weed dry weight in control plot}}{\text{Weed dry weight in treated plot}}$$

Statistical analysis for data recorded on weeds and maize was done following the analysis of variance technique for randomized block design (RBD) as suggested by Gomez and Gomez (1976). Statistical significance was tested by applying F-test at 0.05 level of probability and critical differences were calculated for those parameters which were found significant ($P \leq 0.05$) to compare the effects of different treatments. Based on the prevailing market price of produce and cost of cultivation, gross returns and net returns were computed. Harvest index were calculated as per the standard formulae suggested by Donald and Humblin (1976).

RESULTS AND DISCUSSION

Weed density and weed control efficiency (WCE)

Major weed species observed in experimental field were *Cyperus rotundus* (sedge), *Trianthema portulacastrum, Cleome viscosa, Euphorbia hirta* and *Phyllanthus niruri* (broad-leaved) *Cynodon dactylon, Panicum repens* and *Dactyloctenium aegyptium* (grasses). The relative density of broad leaf weeds-BLW (55.31%) was higher followed by grasses (37.72%) and sedges (8.97%). The weed density and weed control efficiency differed significantly at 30, 45 and 60 DAS due to various weed control treatment (Tables 1 and 2). Pre-emergence application of saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750) mixture caused significant reduction in weed density and WCE at different growth stages over rest of the treatment. The lowest density of sedges (7.50, 9.15 and 13.10 no. m^2 at 30, 45 and 60 DAS, respectively), grasses (20.60, 29.95 and 38.20 no. m^2 at 30, 45 and 60 DAS, respectively) and BLWs (28.80, 39.60 and 49.0 no. m^2 at 30, 45 and 60 DAS, respectively) were recorded with application of saflufenacil 68 g/l+diamethanamid-P 600 g/l EC (85 +750). Similarly, highest WCE of sedges (49.23, 47.07, and 40.53% at 30, 45 and 60 DAS, respectively), grasses (67.63, 57.32 and 52.72% at 30, 45 and 60 DAS, respectively) and BLWs (73.95, 67.91 and 61.42% at 30, 45 and 60 DAS, respectively) were recorded under saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750). This might be due to effective control of weeds for a longer period resulting in low weed dry weight. A pre-mix formulation of saflufenacil/ dimethenamid-P was developed for better control of grassy and broad leaf weeds in sweet corn than saflufenacil alone. Similar findings were also reported by Sahoo *et al*. (2017).

Weed indices and weed dry matter production

Values of weed indices like weed index (WI), crop resistance index (CRI) and herbicide efficiency index (HEI) were the lowest in weedy check (Table 3). Combined application of saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750) recorded the maximum values of WCE (59.56%), CRI (2.30) and HEI (1.66).This treatment proved better than combination of saflufenacil 68 g/l+ dimethanamid-P 600 g/l EC (68+600), saflufenacil 68 g/l+ dimethanamid-P 600 g/l EC (51+450) and alone application

Table 1 Weed density as influenced by different herbicidal treatment (Pooled data of 2 years)

Treatment	Doses (*a.i.*g or ml/ha)	Weed density (no./m^2)								
		Sedges			Grasses			Broad leaf weeds		
		30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
Saflufenacil 68 g/l+ Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	51 + 450	9.50	12.50	15.80	32.10	47.40	55.65	43.05	56.00	66.45
Saflufenacil 68 g/l +Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	68 + 600	7.95	10.35	14.55	26.20	36.55	44.70	35.45	46.45	56.25
Saflufenacil 68 g/l+ Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	85 + 750	7.50	9.15	13.10	20.60	29.95	38.20	28.80	39.60	49.00
Saflufenacil 70% WG	70	9.85	14.05	18.40	36.70	47.40	60.20	60.80	79.80	98.20
Dimethanamid-P 720 g/l	600	12.05	14.00	18.35	38.45	50.65	62.90	29.20	39.10	49.90
Atrazin 50% WP	500	10.20	13.30	17.40	35.95	51.15	67.20	61.85	77.95	108.55
Weed free		1.25	2.10	3.35	3.85	6.25	9.45	3.10	3.90	6.90
Weedy check		14.75	17.45	21.75	63.70	70.20	80.95	97.80	111.95	122.95
SEm±		0.34	0.43	0.55	1.35	1.62	1.94	2.01	2.44	2.83
CD (P=0.05)		1.04	1.31	1.67	4.10	4.90	5.89	6.10	7.39	8.89

of dimethanamid-P 720 g/l (T5) and atrazine 50% WP. Whereas, the lowest weed index (0.05) was recorded with the application of saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750) followed saflufenacil 68 g/l+dimethanamid-P 600 g/l EC (68+600) (T_2). This clearly showed that use of pre-emergence herbicides was most effective in controlling weeds. Among the herbicidal treatments, the lowest total weed dry matter (0.35 t/ha) was recorded in saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85+750), which was significantly superior over rest of the treatments.

Growth and yield attributes

Maximum plant height (165.63 cm) and dry matter accumulation (321.67 g/plant) of maize were observed under weed free treatment (Table 4). Among different herbicide treatment, application of saflufenacil 68 g/l +diamethanamid-P 600 g/l EC (85+750) produced the tallest plant (163.49 cm) and maximum dry matter of maize (320.33 g/plant), which was significantly superior to control. Yield attributes and yields of maize differed due to different herbicide treatment. Weed free treatments

Table 2 Weed control efficiency (%) as influenced by different herbicidal treatment (Pooled data of 2 years)

Treatment	Sedges			Grasses			Broad leaf weeds		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
Saflufenacil 68 g/ l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	35.73	29.55	28.35	49.61	32.48	31.19	52.23	46.63	44.71
Saflufenacil 68 g/ l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	46.25	40.79	33.93	58.88	47.92	44.75	66.14	66.10	58.31
Saflufenacil 68 g/ l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	49.33	47.07	40.53	67.63	57.32	52.72	73.95	67.91	61.42
Saflufenacil 70% WG	34.28	20.95	16.46	53.86	46.94	42.04	57.20	51.49	46.34
Dimethanamid-P 720 g/l	19.17	19.81	16.00	39.63	36.34	30.81	67.07	62.64	56.26
Atrazin 50% WP	28.89	21.50	19.38	43.63	27.14	17.07	43.35	34.88	14.68
Weed free	91.57	87.73	84.60	93.94	91.05	88.26	96.78	95.99	93.33
Weedy check									
SEm±	0.94	0.81	0.77	1.22	1.08	1.00	1.37	1.28	1.17
CD (P=0.05)	2.84	2.47	2.32	3.69	3.29	3.02	4.16	3.87	3.54

Table 3 Total weed dry matter and weed indices as influenced by different herbicidal treatment (Pooled data of 2 years)

Treatment	Doses (*a.i.* g or ml/ha)	Total weed dry matter (t/ha)	Weed control efficiency (%)	Weed index (WI)	Crop resistance index (CREI)	Herbicidal efficiency index (HEI)
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	51 + 450	0.55	36.15	0.31	0.76	0.64
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	68 + 600	0.45	48.32	0.10	1.41	1.17
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	85 + 750	0.35	59.56	0.05	2.30	1.66
Saflufenacil 70% WG	70	0.61	29.66	0.55	0.49	0.33
Dimethanamid-P 720 g/l	600	0.63	27.00	0.37	0.47	0.50
Atrazin 50% WP	500	0.58	33.37	0.50	0.60	0.40
Weed free		0.05	93.74	1.00	23.84	
Weedy check		0.86				
SEm±		0.02				
CD (P=0.05)		0.06				

showed superiority in respect to all yield attributes of crop. Application of 68 g/l + diamethanamid-P 600 g/l EC (85 +750) produced the maximum cob weight (153.89 g/cob) and grain weight (122.35 g/cob) with saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750), which was at par with all herbicidal treatment but significantly superior to control. Significantly higher cob length (17.1 cm) and seed index (29.17 g) were recorded with application of saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750), which was comparable with saflufenacil 68 g/ l+dimethanamid-P 600 g/l EC (68+600), saflufenacil 68 g/ l+dimethanamid-P 600 g/l EC (51+450) and dimethanamid-P 720 g/l and significantly superior than rest of treatment. This could be due to better weed control with application of these herbicide combinations.

Yields

Significant differences were observed in grain, stover and biological yields due to different herbicidal treatments (Table 4). Application of saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750) (T3) and saflufenacil 68 g/l+dimethanamid-P 600 g/l EC (68+600) (T_2) produced grain yield (3.37 and 3.27 t/ha), stover yield (4.17and 4.10 t/ha) and biological yield (7.57 and 7.32 t/ha), respectively; and these treatments were on a par with weed free check, which recorded the highest grain (3.51 t/ha), stover (4.20 t/ha) and biological yields (7.71 t/ha).This might be due to better translocation of photosynthates from source to sink. The lowest maize yields was recorded in weedy check due to severe crop-weed competition.

Table 4 Growth, yield attributes, yields and weed dry matter as influenced by different herbicidal treatment (Pooled data of 2 years)

Treatment	Plant height (cm)	Dry matter/ plant (g)	Cobs/ plant (no.)	Cob weight/ cob (g)	Grain weight/ cob (g)	Cob length (cm)	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Saflufenacil 68 g/l+ Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	160.77	314.63	1.00	150.09	119.33	15.92	26.98	2.87	3.61	6.47	44.25
Saflufenacil 68 g/l+ Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	162.60	318.40	1.00	151.30	120.85	16.54	27.10	3.27	4.07	7.33	44.53
Saflufenacil 68 g/l+ Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	163.49	320.33	1.11	153.89	122.35	17.08	29.17	3.37	4.17	7.57	44.87
Saflufenacil 70% WG	155.28	306.98	1.00	144.17	112.83	14.30	21.81	2.51	3.14	5.65	44.44
Dimethanamid-P 720 g/l	158.40	310.57	1.11	146.89	115.44	14.80	24.62	2.77	3.43	6.20	44.72
Atrazin50% WP	157.20	307.20	1.00	146.03	116.70	14.50	22.95	2.57	3.26	5.83	44.02
Weed free	165.63	321.67	1.22	155.57	124.18	17.80	30.50	3.5.1	4.20	7.71	45.52
Weedy check	148.87	280.00	1.00	134.47	94.33	14.96	20.47	2.03	2.81	4.85	41.95
SEm±	4.63	5.12	0.7	3.24	4.29	0.45	0.87	0.12	0.11	0.18	1.13
CD (P=0.05)	14.04	15.52	0.21	9.83	13.02	1.37	2.65	0.35	0.34	0.55	NS

Table 5 Effect of different doses of new herbicides on nutrient content and uptake by grain and strover (Pooled data of 2 years)

Treatment	Nutrient content (%)						Nutrient uptake (kg/ha)					
	Grain			Stover			Grain			Stover		
	N	P	K	N	P	K	N	P	K	N	P	K
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	1.46	0.23	0.33	0.94	0.13	1.30	41.92	6.66	9.42	33.92	4.58	46.91
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	1.50	0.24	0.33	0.98	0.13	1.34	49.03	7.68	10.85	39.88	5.21	54.53
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	1.53	0.24	0.34	1.01	0.13	1.36	52.06	8.13	11.40	42.08	5.46	56.66
Saflufenacil 70% WG	1.32	0.23	0.32	0.83	0.12	1.24	33.36	5.74	8.14	26.22	3.82	39.17
Dimethanamid-P 720 g/l	1.42	0.23	0.33	0.90	0.12	1.28	39.39	6.36	9.02	30.93	4.26	43.99
Atrazin 50% WP	1.35	0.23	0.32	0.86	0.12	1.27	34.71	5.79	8.28	27.89	3.98	41.39
Weed free	1.58	0.24	0.34	1.03	0.14	1.41	55.33	8.51	11.96	43.26	5.67	59.22
Weedy check	1.29	0.18	0.29	0.80	0.12	1.16	26.33	3.74	5.98	22.45	3.23	32.55
SEm±	0.04	0.01	0.01	0.02	0.003	0.03	2.37	0.47	0.50	1.20	0.19	1.93
CD (P=0.05)	0.12	0.04	0.03	0.07	0.010	0.11	7.18	1.42	1.52	3.64	0.47	5.86

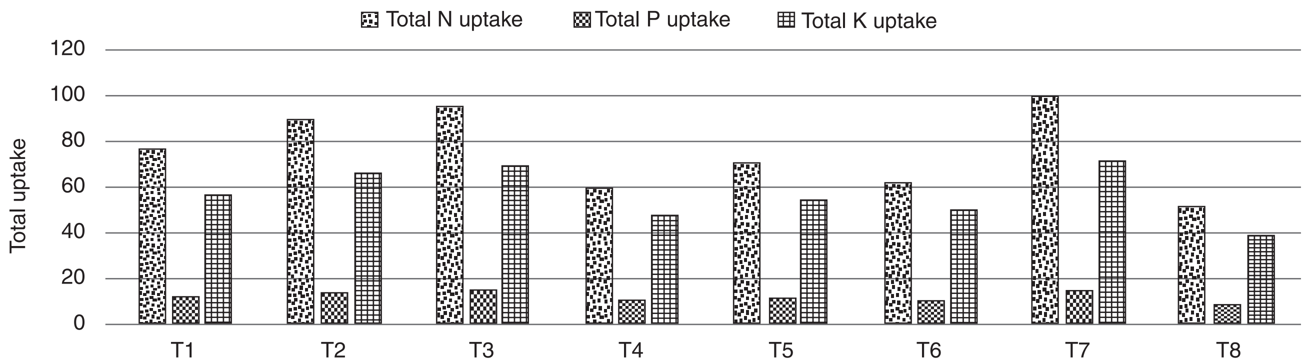

Fig 1 Total nutrient (NPK) uptake by crop as influenced by different herbicidal treatment (Pooled data of 2 years).

Table 6 Effect of different doses of new herbicidal treatment on economics of maize (Pooled data of 2 years)

Treatment	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	Production efficiency (kg/ha/day)	Economic efficiency (₹/ha/day)
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	44458	28608	1.80	22.74	227.05
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	50578	34428	2.13	25.91	273.24
Saflufenacil 68 g/l+Dimethanamid-P 600 g/l EC (Integrity 668 g/l EC)	52525	36125	2.20	26.98	286.70
Saflufenacil 70% WG	38936	22736	1.40	19.94	180.44
Dimethanamid-P 720 g/l	42877	26877	1.68	21.98	213.31
Atrazin50% WP	39943	24443	1.58	20.40	193.99
Weed free	54056	37556	2.28	27.87	298.06
Weedy check	32058	17058	1.14	16.13	135.38
SEm±	1583	1583	0.10	0.92	12.56
CD (P=0.05)	4802	4802	0.30	2.97	38.11

Nutrient content and uptake

Nutrient contents (NPK) in grain and stover, and their uptake were significantly influenced by various herbicidal treatments (Table 5). Weed free treatment showed its superiority in respect to nutrient content and their uptake. Among various treatment, application of saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750) improved the NPK content in grain and stover of maize. Similarly, the highest uptake of N, P and K by grain and stover of maize was recorded under weed free which was on a par with saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750) and saflufenacil 68 g/l+dimethanamid-P 600 g/l EC (68+600), but significantly superior to rest of herbicidal treatments. The highest total uptake of NPK was recorded in weed free followed by saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750) and saflufenacil 68 g/l+dimethanamid-P 600 g/l EC (68+600) (Fig 1).This was due to better control of weeds at critical period of crop growth resulting better availability of nutrients to crop (Sahoo *et al*. 2017).

Economics

Significant differences were noted in gross returns, net returns, B: C ratio, production and economic efficiency due to different herbicidal treatment (Table 6). Weed free treatments proved superiority among all treatments in respect to economics and efficiencies. Among the herbicidal treatments, maximum gross returns (₹ 52 525/ ha), net returns (₹ 36 125/ha) and B:C ratio (2.20) were recorded under saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750), which was statistically similar with saflufenacil 68 g/l+dimethanamid-P 600 g/l EC (68+600) and significantly superior to rest of treatment. Similarly, the highest production efficiency (26.68 kg/ha/day) and economic efficiency (286.24 ₹/ha/day) were also noted with saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85 +750) which was found at par with saflufenacil 68 g/ l+dimethanamid-P 600 g/l EC (68+600).

Hence, it may be concluded that pre-emergence application of saflufenacil 68 g/l + diamethanamid-P 600 g/l EC (85+750) provided better weed suppression and higher yield of maize under rainfed condition of Jhabua Hills of Madhya Pradesh.

REFERENCES

Anonymous.2014. Adoption of improved variety of maize in India organized by National Institute of Agriculture Economics and Policy Research (ICAR-NAIP) Pusa, New Delhi during 12th May 2015 at JNKVV, Jabalpur.

Donald C M and Hamblin J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Advances in Agronomy* **28**: 361–405.

Gomez K A and Gomez A A. 1976. *Statistical Procedures Procedures for Agricultural Research,* 2nded John Wiley and Sons Inc., New York, USA.

Grossmann K, Niggeweg R, Christiansen N, Looser R and Ehrardt T. 2010. The herbicide saflufenacil (Kixor) is a new inhibitor of protoporphyrinogen IX oxidase activity. *Weed Science* **58**: 1–9.

Jha P, Kumar V, Garcia J and Reichard N. 2015.Tank mixing pendimethalin with pyroxasulfone and chloroacetamide herbicides enhances in-season residual weed control in corn. *Weed Technology* **29** (2): 198–206.

Kumar B, Prasad S, Mandal D and Kumar R. 2017. Influence of integrated weed management practices on weed dynamics, productivity and nutrient uptake of *rabi* maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences* **6**(4): 1431–40.

Kumar R and Bohra J S. 2014. Effect of NPKS and Zn application on growth, yield, economics and quality of baby corn. *Archives of Agronomy and Soil Science* **60**(9): 1193–206.

Kumar R, Bohra J S, Kumawat N and Singh A K.2015. Fodder yield, nutrient uptake and quality of baby corn (*Zea mays* L.) as influenced by NPKS and Zn fertilization. *Research on Crops* **16**(2): 243–9.

Mandal D, Singh D, Kumar R, Kumari A and Kumar V.2011. Effects on production potential and economics of direct seeded rice sowing dates and weed management techniques. *Indian Journal of Weed Science* **43** (3&4): 139–44.

Mishra M and Misra A.1997. Estimation of integrated pest management index in jute-A new approach. *Indian Journal of Weed Science* **29**: 39–42.

Neupane M P, Singh R K, Kumar R and Kumari A. 2011a. Yield performance of baby corn (*Zea mays* L.) as influenced by nitrogen sources and row spacing. *Environment and Ecology* **29** (3): 1180–3.

Neupane M P, Singh R K, Kumar R and Kumari A. 2011c. Quality and yield performance of baby corn (*Zea mays* L.) as influenced by nitrogen sources and row spacing. *Environment and Ecology* **29** (3A): 1215–8.

Neupane M P, Singh R K, Kumar Rakesh and Kumari A. 2011b. Response of baby corn (*Zea mays* L.) to nitrogen sources and row spacing. *Environment & Ecology* **29** (3): 1176–9.

Patel V J, Upadhyay P N, Patel J B and Meisuriya M I. 2006. Effect of herbicide mixture on weeds in *kharif* maize (*Zea mays* L.) under middle Gujarat conditions. *Indian Journal of Weed Science* **38** (1&2): 54–7.

Pradeep L S, Girijesh G K, Sharanabasappa, Narayan S M and Natarju S P. 2017. Efficacy of pre emergence herbicides on weed dynamics and yield of maize (*Zea mays* L.). *International Journal of Pure and Applied Bioscience* **5** (5): 629–35.

Sahoo T R, Huihalli U K, Paikaray R K and Mohapatra U. 2017. Weed dry matter, weed control efficiency and nutrient uptake by weeds as affected by weed management practices in maize. *Environment and Ecology* **34** (4): 2781–5.

Sarkar B, Kumar R, Mishra J S and Bhatt B P. 2016. Comparative performance of different weeding tools in winter maize (*Zea mays* L.). *Indian Journal Weed Science* **48** (3): 330–2.

Shivran R K, Kumar Rand Kumari A. 2013. Influence of sulphur, phosphorus and farm yard manure on yield attributes and productivity of maize (*Zea mays* L.) in humid south eastern plains of Rajasthan. *Agricultural Science Digest* **33** (1): 9–14.

Soltani N, Richard J, Vyn Laura L, Van Eerd, Shropshire C and Sikkema P H. 2012. Effect of reduced herbicide rates on weed control, environmental impact and profitability of corn. *Canadian Journal of Plant Science* 969–75.

Trolove M R, Rahman A, Hagerty G C and James T K. 2011. Efficacy and crop selectivity of saflufenacil alone and with partner herbicides for weed control in maize. *New Zealand Plant Protection* **60**: 133–41.