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Bio efficiency of post emergent herbicide in maize under rain fed conditions of Kashmir

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Abstract
A field experiment entitled: "Bio efficiency of post emergent herbicide in maize under rain fed conditions of Kashmir" was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology, FoA, wadura during *kharif* season of 2020 to 2021. The experiment was laid out in Randomized block design with ten weed management practices Atrazine @ 1.0 kg / ha (PE) *fb* one hand weeding (HW) at 35 DAS(T_1), Atrazine @ 0.5 kg / ha (PE) *fb* tembotrione @ 120 g / ha at 35 DAS (T_2), Atrazine @ 0.5 kg / ha (PE) *fb* topramezone @ 25.2g / ha (POE) at 35 DAS (T_3), Metribuzin @ 0.5 kg / ha (PE) *fb* one hand weeding at 35 DAS (T_4), Metribuzin @ 0.25 kg / ha (PE) *fb* tembotrione 120g / ha (POE) at 35 DAS (T_5), Metribuzin @ 0.25 kg / ha (PE) *fb* topramezone @ 25.2g / ha (POE) at 35 DAS (T_6), Intercropping with smoother cowpea (T_7), Two HW at 25 and 50 DAS (T_8), Weed free (T_9), Weedy check (T_{10}). The soil of the experimental field was silty clay loam in texture, neutral in reaction with low N (220 kg ha^{-1}) and P (23.5 kg ha^{-1}) and medium in K (165.5 $kgha^{-1}$). Among herbicides Atrazine @ 0.5 kg ha^{-1} (PE) *fb* tembotrione @ 120g ha^{-1} at 35 DAS (T_2) recorded highest growth parameters plant height (207.45 cm and 212.42 cm), dry matter accumulation (134.29 q ha^{-1} and 136.68 qha^{-1}), leaf area index (6.75 and 6.81) as well as yield parameters grain yield (50.33 and 52.04 q / ha) and Stover yield 60.67 and 63.05 q / ha) during both seasons. It can concluded that under existing conditions Atrazine @ 0.5 kg ha^{-1} (PE) *fb* tembotrione @ 120g ha^{-1} at 35 DAS should be recommended proved superior for realizing higher yield and profitability of maize (composite-8) under Kashmir conditions.

Keywords: Growth attributes, herbicide, hand weeding, yield

Introduction
Globally, maize is known as Queen of Cereals and is the world's leading crop having wider adaptability under varied agro-climatic conditions. The crop is multipurpose and is being used as food, animal feed, fodder and for bio-energy production. The crop is grown in about 160 countries possessing wider diversity of soil, climate, biodiversity and management practices for its cultivation. Globally, Maize is cultivated on an area of 180 mha with a production of 1050 m tons ha^{-1} and productivity of 5.5 m tons ha^{-1} (FAO 2018-19) [4]. In India, maize is cultivated on an area of 10.3 m ha with a production of 26.26 m tons and productivity 2.6 tons ha^{-1}(DES 2018-19) [3]. In Kashmir valley area under Maize is about 3.1 lakh ha and production is 52.7 lakh quintals with a productivity of 1.7tons ha^{-1} (DES 2018-19) [3].

Apart from many other constraints, poor productivity of the crop is attributed to poor weed management. The growth conditions can be made favourable for the crop through effective use of weed management practices. The combination of pre-emergence and new post-emergence herbicide with hand weeding need to be evaluated for their effect on maize and its associated weed flora.

Nature has bestowed Jammu and Kashmir with agro climatic conditions conducive for maize cultivation and has a strong comparative advantage in its production. Weeds are perceived by the farming community as being the greatest cause of yield loss in maize crop. They are the main competitors of maize for light, water, nutrients, space, carbon dioxide etc. and increase the cost of production. The total economic losses of weeds will be much higher, if indirect effect of weeds on health, loss of biodiversity, nutrient depletion and grain quality is taken under consideration. Further, stress related to farm activity in general and weeding in particular, compels the young generation to resign from farming and opt for other options of livelihood. Various strategies have been formed throughout the world to curb the weed menace in the maize crop but their effectiveness varies from place to place owing to many factors.

Maize crop is infested with a diversity of upland weeds which result in yield losses of 60-81% (Sen *et al*. 2000) [12]. Farmers usually give prime importance to few cultural practices and neglect other factors like weed control. Maize crop gets infested with a variety of weeds and experiences a heavy weed competition which often inflicts huge losses ranging from 28 to 100% (Patel *et al*., 2006) [11]. Weed management strategies are aimed to limit at the deleterious effects of weeds growing with crop plants. These effects could be quite variable but the most common is competition for available resources *viz*., light, nutrient, moisture and space particularly at the initial stages of crop growth. The extent of nutrient loss varies from 30-40% of the applied nutrients (Mundra *et al*., 2002) [8]. This results in the drastic reduction of yield and quality of final produce (Kandasamy, 2017) [7]. The extent of reduction in grain yield of maize has been reported to be in the range of 33 to 50% depending on the intensity and persistence of weed density in standing crop (Sharma *et al*., 2000) [13]. Manual weeding though very effective in controlling weeds, very often is cumbersome, labour intensive, expensive and time consuming (Warade *et al*., 2006) [20].

Herbicides have become obligatory for increasing the agricultural production and to maintain the cropped area free from weeds and pests. In order to achieve enhanced crop production and higher benefits from applied inputs, weeds must be kept under check by any of the safe and effective means. Uses of pre-emergent and post-emergent herbicides are more effective weapons in tackling weed menace and thereby nutrient removal by them. As the weeds interfere during the growth of the crop, post emergence herbicides may help in avoiding the problem of weeds at later stages. Tembotrione, a new post emergent broad spectrum systemic, pigment synthesis inhibitor herbicide, inhibits 4-HPPD enzyme. Tembotrione is reported to remain active in the soil throughout the growing season, offering control of grass and broadleaf weeds until corn canopy closure (Almsick *et al.*, 2009) [1]. Managing weeds through pre emergence and post emergence herbicides could be an ideal means for controlling the weeds in view of their economics and effectiveness in maize and attributed to higher weed-control efficiency resulting in more favorable environment for growth and development of crop plants apparently due to lesser weed competition which led to increased growth of crop and thereby increase in nutrient uptake by improving the leaf area, dry matter accumulation leading to better yield attributes and accumulation of higher amounts of nutrients in maize grains (Akhtar *et al.* 2017) [22]. Post emergence (POST) herbicide application is an essential option in crops like maize, as escaped weeds or the later flushes of weeds may compete with the crop and contribute seed to the weed seed bank (Vahedi *et al*., 2013) [21]. The field efficacy of tembotrione as post-emergence against mixed weed flora in maize was evaluated in the present study in research experiments.

Materials and Methods

A field experiment entitled: "Bioefficiency of post emergent herbicide in maize under rain fed conditions of Kashmir" was conducted during 2020 -21 at the Experimental Farm of the Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir at Wadura, Sopore. The site is situated between 34º 21′ N and 74º 23′ E at an altitude of 1590 meters above mean sea level. The climate is temperate cum Mediterranean and continental type characterized by hot summers and severe winters. The average annual precipitation is 812 mm (average over past thirty years) and more than 80 per cent of precipitation is received from western disturbances. The mean meteorological data for the cropping season of 2020 to 21 recorded at Meteorological Observatory at Faculty of Agriculture, Wadura, Sopore. It is evident that maximum and minimum temperatures were 28 °C and 13.05 °C, respectively and the total precipitation amounted to 248.6 mm during crop growth period. The total numbers of sunshine hours recorded during the crop growth period were 142.24 and the mean maximum and minimum relative humidity were 80.53 percent and 67.51 percent, respectively during the crop growth period. Composite soil samples collected from 0 to 15 cm soil depth at the start of experiment during 2020 to 21 were subjected to mechanical and chemical analysis. The results revealed that the soil was clay loam in texture, medium in organic carbon, low in available nitrogen, phosphorus and potassium with neutral pH. The experiment consists of ten factors *viz,* weed management practices, (T_1) Atrazine @ 1.0 kg / ha (PE) *fb* one hand weeding (HW) at 35 DAS,(T_2) Atrazine @ 0.5 kg / ha (PE) *fb* tembotrione @ 120 g / ha at 35 DAS, (T_3) Atrazine @ 0.5 kg / ha (PE) *fb* topramezone @ 25.2 g / ha (POE) at 35 DAS, (T_4) Metribuzin @ 0.5 kg / ha (PE) *fb* one hand weeding at 35 DAS, (T_5) Metribuzin @ 0.25 kg / ha (PE) *fb* tembotrione 120 g / ha (POE) at 35 DAS, (T_6) Metribuzin @ 0.25 kg / ha (PE) *fb* topramezone @ 25.2 g / ha (POE) at 35 DAS, (T_7) Intercropping with smoother cowpea, (T_8) Two Hand weeding at 25 and 50 DAS, (T_9) Weed free, (T_{10}) Weedy check laid out in RCBD with three replications. The P_2O_5 and K_2O were applied basally @ 60 and 30 kg/ha.Composite-8 variety of maize was used as test crop. The crop was irrigated four times each at critical stage of the crop. A spacing of 60 cm x 20 cm was used *i.e.*, a population of 83000 plants / ha. Recommended of dose 60 kg / ha P_2O_5 and 40 kg / ha K_2O was applied as basal application.

Results and Discussion

Growth attributes

Plant height: The data pertaining to the growth parameters *viz.* plant height, dry matter production, leaf area index, no of functional leaves *viz.* were observed to be significantly higher in weed free treatment (T_9). Among herbicides atrazine 1.5 kg a.i ha^{-1} as pre emergence + tembotrione 120 g a.i ha^{-1} as post emergence at 35 DAS (T_2) recorded higher plant height, as tembotrione is a new selective post-emergence herbicide for the control of broad leaf and grassy weeds in maize. The possible reason for beneficial effect could possibly be attributed to higher weed-control efficiency with these treatments resulting in more favorable environment for growth and development of crop plants apparently due to lesser weed competition which led to increase height of maize plant. Our results in conformity with the results of Singh *et al*. (2012) [15].

Dry matter accumulation: Among herbicides atrazine 1.5 kg a.i ha^{-1} as pre emergence + tembotrione 120 g a.i ha^{-1} as post emergence at 35 DAS (T_2) recorded highest dry matter accumulation which is at par with weed free treatment (T_9) it might be due to when atrazine as pre emergence was applied along with tembotrione as post emergence is resulted in excellent control of grassy weeds and thereby reduce crop weed competition for light, space, nutrients and results increase in nutrient uptake by improving the leaf area, and more leaf area contributed increased source –sink relationship and in this way resulted more dry matter accumulation. Maximum dry weight of maize under weed-free treatment was also reported by Malviya and Singh (2007) [9]. Similar results were reported by Hurle *et al.* (1996) [23].

Leaf area index: Atrazine 1.5 kg a.i ha^{-1} as pre emergence + tembotrione 120 g a.i ha^{-1} as post emergence at 35 DAS (T_2) recorded highest number of leaves which is at par with weed free treatment (T_9) and thereby increase in nutrient uptake by improving the leaf area, dry matter accumulation leading to better yield attributes and accumulation of higher amounts of nutrients in maize grains. Similar findings were reported by Mundra *et al.*, (2002) [8].

Yield attributes and yield: Weed management practices significantly influenced the yield contributing characters *viz.* number of cobs plant^{-1}, grains row^{-1} varied significantly amongst different weed management practices. In both the years the highest cob yield was recorded with the application of Tembotrione at 120 g ha^{-1} along with pre emergence application of atrazine (T_2). However, no. of cobs per plant was unaffected by the different weed control treatments. Our results are in conformity with singh *et al.* 2012 [15].

The least yield contributing attributes were recorded in weedy check plots (T_{10}). The increase in the yield attributes *viz.*, number of grains in a row, total number of grains per cob, with weed control practices might be due to higher weed control efficiency and lower weed competition which resulted in better growth and development of maize which led to higher photosynthetic activities that resulted in the production of enough assimilates for subsequent translocation from vegetative parts to developing grains. Similar observation was made by Walia *et al.* (2007) [19] and Nadiger *et al.* (2013) [10]. Malviya and Singh (2007) [9] also reported that the yield contributing characters were significantly influenced due to weed-control measures. Highest number of cobs plant^{-1} was recorded in weed free plot and lowest number of cobs was recorded in weedy check plots. Maximum number of grains cob^{-1}, cobs plant^{-1} was recorded in weed free (T_9) treatment followed by (T_2) and minimum in weedy check. Among herbicide treatments, maximum cob length was recorded with atrazine 1.5 kg ha^{-1} pre emergence + tembotrione 120 g ha^{-1} as post emergence at 35 DAS (T_2). Our findings are supported by Singh (2017) [16] and Swetha (2015) [17].

Table 1: Effect of weed management practices on growth parameters (cm) of maize

Treatments	Plant height (cm)		Dry matter accumulation(q/ha)		Leaf area index	
Weed management	2020	2021	2020	2021	2020	2021
(T_1) Atrazine @ 1.0 kg / ha (PE) *fb* one hand weeding (HW) at 35DAS	190.97	193.34	119.35	123.31	5.05	5.67
(T_2) Atrazine @ 0.5 kg / ha (PE) *fb* tembotrione @120 g / ha at 35 DAS	207.45	212.42	134.29	136.68	6.75	6.81
(T_3) Atrazine@ 0.5 kg / ha (PE) *fb* Topramezone@ 25.2 g / ha (POE) at 35 DAS	193.93	198.78	122.81	128.41	6.33	6.43
(T_4) Metribuzin @ 0.5 kg / ha (PE) *fb* one hand weeding at 35 DAS	192.77	197.21	120.93	125.30	6.05	6.07
(T_5) Metribuzin @ 0.25 kg / ha (PE) *fb* tembotrione 120 g / ha (POE) at 35DAS	198.48	202.46	128.55	131.99	6.45	6.66
(T_6) Metribuzin @ 0.25kg / ha(PE)*fb* topramezone @ 25.2 g / ha (POE) at 35 DAS	197.78	200.35	125.31	130.03	6.40	6.52
(T_7) Intercropping with smoother Cowpea	204.91	209.76	131.81	134.49	6.72	6.74
(T_8) Two HW at 25 and 50 DAS	189.35	193.93	117.55	120.48	5.11	5.85
(T_9) Weed free	211.08	220.16	135.58	139.92	6.84	6.89
(T_{10}) Weedy check	182.49	185.43	112.29	117.44	4.19	4.84
SEm±	2.17	1.97	3.48	3.93	0.38	0.39
CD ($p \leq 0.05$)	6.51	5.89	10.44	11.77	1.16	1.19

Table 2: Effect of weed management practices on No. of cobs / plant, no. of grains/cob, seed index (g)

Treatments	No. of cobs / plant		No. of grains / cob		Seed index	
Weed management	2020	2021	2020	2021	2020	2021
T_1 Atrazine @ 1.0 kg / ha (PE) *fb* one hand weeding (HW) at 35 DAS	1.05	1.14	255.25	269.26	18.77	19.81
T_2 Atrazine @ 0.5 kg / ha (PE) *fb* tembotrione @ 120 g / ha at 35 DAS	1.73	1.79	315.00	317.59	23.27	24.74
T_3 Atrazine @ 0.5 kg / ha (PE) *fb* topramezone @ 25.2 g / ha (POE) at 35 DAS	1.24	1.30	277.75	280.80	20.88	21.52
T_4 Metribuzin @ 0.5 kg / ha (PE) *fb* one hand weeding at 35 DAS	1.14	1.18	270.89	277.69	19.81	20.80
T_5 Metribuzin @ 0.25 kg / ha (PE) *fb* tembotrione 120 g / ha (POE) at 35 DAS	1.48	1.56	306.22	308.64	21.90	23.19
T_6 Metribuzin @ 0.25 kg / ha (PE) *fb* topramezone @ 25.2 g / ha (POE) at 35 DAS	1.33	1.36	300.84	299.99	20.96	21.92
T_7 Intercropping with smoother cowpea	1.66	1.71	310.54	313.68	22.37	23.86
T_8 Two HW at 25 and 50 DAS	1.03	1.09	299.02	303.28	21.54	23.11
T9 Weed free	1.80	1.84	325.70	329.78	24.55	26.02
T_{10} Weedy check	0.83	0.98	230.08	239.88	14.71	15.94
SEm±	0.31	0.31	5.24	7.20	0.56	0.51
CD ($p \leq .05$)	N / S	N / S	15.71	21.56	1.67	1.54

Table 3: Effect of weed management practices on weed density (no.m^{-2}) and weed control efficiency

Treatments	Weed density		Weed control efficiency	
Weed management	2020	2021	2020	2021
T_1 Atrazine @ 1.0 kg / ha (PE) *fb* one hand weeding (HW) at 35 DAS	(74.70) **8.68	(73.70) **8.62	28.12	34.61
T_2 Atrazine @ 0.5 kg / ha (PE) *fb* tembotrione @ 120 g / ha at 35 DAS	(36.86) **6.14	(35.56) **5.98	57.71	60.38
T_3 Atrazine @ 0.5 kg / ha (PE) *fb* topramezone @ 25.2 g / ha (POE) at 35 DAS	(69.30) **8.38	(56.86) **7.60	34.26	42.70
T4 Metribuzin @ 0.5 kg / ha (PE) *fb* one hand weeding at 35 DAS	(72.24) **8.55	(70.34) **8.44	32.19	38.79
T_5 Metribuzin @ 0.25 kg / ha (PE) *fb* tembotrione 120 g / ha (POE) at 35 DAS	(45.10) **6.78	(41.34) **6.53	51.15	54.88
T_6 Metribuzin @ 0.25 kg / ha (PE) *fb* topramezone @ 25.2 g / ha (POE) at 35 DAS	(73.98) **8.64	(63.92) **8.05	43.29	50.53
T_7 Intercropping with smoother cowpea	(44.50) **6.74	(42.17) **6.56	64.60	68.38
T_8 Two HW at 25 and 50 DAS	(49.18) **6.03	(44.83) **5.67	60.08	61.00
T_9 Weed free	0	0	100.0	100.0
T_{10} Weedy check	(99.50) **10.0	(89.08) **9.46	0.00	0.00
SEm±	0.24	0.30	1.49	1.76
CD ($p \leq .05$)	0.74	0.90	4.47	5.28

Weed density and weed control efficiency (%): The weed management treatments significantly influenced the weed density and weed control efficiency. Among herbicides application of atrazine @ 1 kg a.i ha^{-1} (pre-emergence) followed in combination of Tembotrione @ 120 g a.i ha^{-1} (post-emergence) at 35 days after sowing was found most effective to control the grassy as well as non-grassy weeds as compared to other herbicidal treatments either applied as pre- or post-emergence with maximum weed control efficiency as well as recorded lowest weed density. Kaur *et al.* (2018) reported the same results.

During both years Weedy check treatment (T_{10}) recorded significantly higher total weed density at knee high (68.25 m^{-2}) and (61.21 m^{-2}) tasseling (99.50 m^{-2}) and (89.08 m^{-2}) and harvesting stages (112.13 m^{-2}) and (100.33 m^{-2}) and the lowest weed density was recorded in weed free plot (T_9). This might be due to the continuous removal of weeds under hand weeding treatment that resulted in lowest weed density. These results are in conformity with the results of Singh and Sheoran (2008) [24] and Singh *et al*. (2009) [14]. The minimum weed control efficiency was recorded in weedy check plots. These results are in accordance with the results indicated by Tripati *et al*. (2005) [25] and Kolage *et al*., (2004) [5].

Conclusion

From this study it is concluded that under existing conditions Atrazine @ 1 kg a.i ha^{-1} (pre-emergence) followed in combination of Tembotrione @ 120 g a.i/ha (post-emergence) at 35 days after sowing can be used for effective control of grasses and broadleaf weeds in maize but at the same time research is required to be undertaken at different locations of the valley before final recommendations are made. Repeated hand weeding in weed free treatment was effective in controlling the weeds and recording higher grain yield, but is not cost effective due to higher labour cost and which is cumbersome too.

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