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Response of Cowpea [*Vigna unguiculata* (L.) Walp.] as Succeeding Crop to Residual Effect of Extreme Levels of Atrazine Administered in Preceding Maize (*Zea mays* L.)

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ABSTRACT

Background: Globally, grain legumes are the paramount family of agricultural crops following cereals. Generally, sequence cropping has manifested effectual in increasing farm productivity and profitability. However, sometimes herbicides administered in previous crop may be associated with phytotoxic effects that can later cause damage to the succeeding crops. The present study aimed to understand the residual effect of extreme levels of atrazine on succeeding cowpea under maize-cowpea cropping system.

Methods: Field experiments were conducted during *Kharif* and *rabi* season of 2019-20 and 2020-21 in a randomized block design with eleven treatments, replicated thrice.

Result: Residual effect of pre-emergence atrazine at 0.50 kg *a.i* ha^{-1} followed by tembotrione at 120g *a.i* ha^{-1} as post-emergence at 25 DAS recorded the lowest total weed density (4.41), total weed dry weight (9.81 g m^{-2}) and highest weed control efficiency (39.25%) during *rabi* 2019-20 while during *rabi* 2020-21 lowest total weed density (5.03), total weed dry weight (10.68 g m^{-2}) and highest weed control efficiency (39.65%) were noticed in pre-emergence atrazine 50% WP at 2.00 kg *a.i* ha^{-1}. Highest seed yield (788.67 and 842.33 kg ha^{-1}) was obtained in weed free treatment.

Key words: Atrazine, Cowpea, Maize, Residual effect.

INTRODUCTION

Maize (*Zea mays* L.) is regarded as one of the prospective drivers of crop diversification under different circumstances and it is cultivated in sequence with different crops under several agro - ecologies of the globe. This is attributed to its vast adaptability and compatibility under diverse soil and climatic conditions. Climate change either globally or regionally, endangers universal food and economic security (Adarsh *et al*., 2019). Worldwide, more than eight hundred million people are suffering from profound hunger and malnutrition (FAO, 2018). Growing pulses could be the best answer to the above mentioned problems as they require minimum inputs, water, management practices and are high in nutrition. Cowpea [*Vigna unguiculata* (L.) Walp.] is among the pulses and it is known as a drought tolerant crop and its broad and drooping leaves retain the soil characteristics particularly maintaining soil moisture owing to the shading effect (Tiwari and Shivhare, 2016). Production of cowpea is estimated at over 8.9 million metric tonnes per year on about 14.4 million hectares globally (FAOSTAT, 2020). In India, cowpea is cultivated in an area of 58 000 hectares with the production of 4.8 lakh tonnes and the productivity of 8.44 t/ha (Aghora, 2018). Numerous factors such as climatic condition, pests and diseases, weeds and water quality are accountable for the lower yield of crops (Tandzi and Mutengwa, 2020). Nevertheless, weeds play a significant role and are known to lessen agricultural output and profitability in various ways, for example by competing with cultivated crops for vital resources *viz*. water, nutrient, light and space, depreciating the main crop as well as increasing production costs throughout their control (Gupta *et al*. 2018). Manual methods like hand weeding and hoeing are effectual in managing weed population. However, they are laborious, tedious, time consuming and requires exorbitant cost inputs hence not economical to farmers (Singh *et al*. 2019). Furthermore, the high demand for labour during peak periods and its paucity have led to the use of herbicides to control weeds in maize. So to conquer these constraints utilization of herbicides for weed management in maize is a magnificent alternative to manual weeding (Getachew and Mekdes, 2017) owing to being economical and less labour dependent (Kurre *et al*. 2017). Among the herbicides employed to control weeds in maize, atrazine is one of the most extensively used herbicides by Indian maize growers. It is a photosynthesis inhibiting herbicide utilised in agriculture as a selective pre-and-post emergence for control

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of grass and broad-leaved weeds in crops such as sugarcane, sorghum, millet and maize (Zhao *et al*., 2017). The herbicide must remain in active and available form in the soil to effectively control weeds until its motive is attained. Nevertheless, due to the high activity of the soil reaction, the amount of time that the atrazine remains vital in the soil is of particular significance, as it may be associated with phytotoxic effects that can later damage the succeeding crops (Rani *et al*., 2021). Little is known about persistence and effect of extreme levels of atrazine in maize-cowpea cropping system. Consequently, considering the above facts, field research was carried out to study the effect of extreme levels of atrazine on weed dynamics and their residual effect on succeeding cowpea crop.

MATERIALS AND METHODS

Field experiments were conducted at Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore, during *Kharif* and *rabi* seasons of 2019-20 and 2020-21. The experimental farm is geographically situated in the Western agro-climatic zone of Tamil Nadu (11°N, 77°E) and at an altitude of 426.72 m above mean sea level. Composite initial soil samples were collected prior to the experiment, pooled and analysed for physico-chemical characteristics. The soil of the experimental field was sandy clay loam in texture classified taxonomically as *Typicustropept.* The soil was high in available potassium (469.2 kg ha^{-1}), low in available nitrogen (246.4 kg ha^{-1}), available phosphorus (6.68 kg ha^{-1}) and organic carbon (0.29%). A total rainfall of 46.5 mm was received in 2 rainy days during the cropping period of cowpea (January 2020 to April 2020) while 220 mm was received in 20 rainy days during the cropping period (November 2020 to February 2021). The field experiment was laid out as a randomized block design (RBD) with three replications. The experiment was composed of 11 treatments namely pre-emergence atrazine 50% WP at 0.50 kg *a.i* ha^{-1} (T_1), pre-emergence atrazine 50% WP at 0.75 kg *a.i* ha^{-1} (T_2), pre-emergence atrazine 50% WP at 1.00 kg *a.i* ha^{-1} (T_3), pre-emergence atrazine 50% WP at 1.25 kg *a.i* ha^{-1} (T_4), pre-emergence atrazine 50% WP at 1.50 kg *a.i* ha^{-1} (T_5), pre-emergence atrazine 50% WP at 1.75 kg *a.i* ha^{-1} (T_6), pre-emergence atrazine 50% WP at 2.00 kg *a.i* ha^{-1} (T_7), pre-emergence atrazine 50% WP at 0.50 kg *a.i* ha^{-1} followed by tembotrione at 120 g *a.i* ha^{-1} as post-emergence at 25 DAS (T_8), pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1} followed by hand weeding at 30 DAS (T_9), weed free check (T_{10}) and weedy check (control) (T_{11}). The gross plot size was 4.8 m x 4.5 m. As per the treatments schedule, atrazine (50% WP) was applied as pre-emergence at 2 days after sowing of maize. Cowpea [var. Co (CP) 7] was raised in the same undisturbed layout of the experimental field on the 11th January 2020 and 6th November 2020 as a succeeding crop to find the residual effect of atrazine administered to *Kharif* maize on 14th September 2019 and 10th July 2020 and harvested on 30th December 2019 and 22nd October 2020 during *Rabi,* 2019 and 2020 respectively.

Cowpea seeds were sown adopting a recommended spacing of 45 cm and 15 cm inter and intra row spacing respectively. The seed rate adopted was 25 kg ha^{-1}. The recommended dose of 25: 50: 25 kg NPK ha^{-1} was applied in the form of Urea (46% N), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O). Full dose of fertilizer NPK was applied basally before sowing. During the entire raising of cowpea, weeding was not performed in all plots apart from weed free ones because cowpea was raised to investigate the residual effect of atrazine administered to maize crop. All other recommended management practices (irrigation, foliar application, pest management) were followed as per the recommendations of Crop Production Guide of Tamil Nadu Agricultural University (CPG, 2019). Parameters taken for observations included total weed density and weed dry weight, weed control efficiency, germination percentage, plant height, plant dry weight, number of pods plant^{-1}, 100-seed weight, seed yield, haulm yield and harvest index. The data on biometric observations and weeds were subjected to Analysis of Variance (ANOVA) using AGRES software version 7.01. Least Significant difference (LSD) (P = 0.05) was used for separation of means. The data on weed parameters were subjected to the square root transformation $\left(\sqrt{x+0.5}\right)$ and statistically analysed by following the method suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Residual effect on weeds

Floristic composition of the experimental field

During the two year field study, the experimental field was infested with miscellaneous flora of both narrow-leaved and broad-leaved weeds. Pivotal narrow-leaved weeds were *Cynodon dactylon, Dactyloctenium aegyptium, Dinebra retroflexa, Echinochloa colona* L.*, Chloris barbata, Brachiaria reptans* and *Cyperus rotundus* while key broad-leaved included *Trianthema portulacastrum*, *Parthenium hyspterophorus*, *Corchorus olitorius* L., *Digera arvensis* and *Boerhavia erecta* L. During *rabi* seasons, *Parthenium hyspterophorus* was the most dominating broad-leaved weed whereas *Echinochloa colona* L. and *Chloris barbata* dominated the narrow-leaved weeds.

Total weed density and dry weight

At harvest, total weed density and weed dry weight were significantly influenced by residual effect of extreme levels of atrazine employed in preceding maize in both *rabi* seasons (Table 1). Herbicidal treatments significantly decreased the two parameters over weedy check (T_{11}). Significant lower total weed density (4.41/m^2) was noticed in residual effect of pre-emergence (PE) atrazine at 0.50 kg a.i ha^{-1} followed by Tembotrione at 120 g *a.i* ha^{-1} as post-emergence at 25 DAS (T_8) during *rabi* 2019-20 and was statistically at par with PE atrazine at 1.00 kg *a.i* ha^{-1}(T_3), PE atrazine at 1.50 kg a.i ha^{-1} (T_5) and PE atrazine at 0.50

Table 1: Residual effect of extreme levels of atrazine on total weed density, total weed dry weight and weed control efficiency at harvest of cowpea.

Treatment	Total weed density (No. m^{-2})		Total weed dry weight (g m^{-2})		Weed control efficiency (%)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1: Pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1}	5.04(25.00)	6.41(40.67)	11.44(130.53)	11.85(139.97)	17.27	25.62
T_2: Pre-emergence atrazine 50% WP at 0.75 kg a.i ha^{-1}	5.02(24.67)	5.66(32.33)	10.93(120.57)	12.00(143.87)	23.58	23.54
T_3: Pre-emergence atrazine 50% WP at 1.00 kg a.i ha^{-1}	4.67(21.33)	5.07(25.33)	11.18(125.60)	11.60(134.97)	20.39	28.27
T_4: Pre-emergence atrazine 50% WP at 1.25 kg a.i ha^{-1}	5.01(24.67)	5.77(33.00)	10.36(107.27)	12.29(151.03)	32.01	19.74
T_5: Pre-emergence atrazine 50% WP at 1.50 kg a.i ha^{-1}	4.72(22.00)	5.36(28.33)	11.88(140.73)	12.21(148.63)	10.80	21.01
T_6: Pre-emergence atrazine 50% WP at 1.75 kg a.i ha^{-1}	5.08(25.33)	5.51(30.00)	11.63(135.83)	12.42(154.00)	13.91	18.16
T_7: Pre-emergence atrazine 50% WP at 2.00 kg a.i ha^{-1}	5.14(26.00)	5.03(25.00)	10.22(104.23)	10.68(113.57)	33.94	39.65
T_8: Pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1} followed by tembotrione at 120 g a.i ha^{-1} as post-emergence at 25 DAS	4.41(19.00)	5.91(35.00)	9.81(95.83)	11.05(121.87)	39.25	35.23
T_9: Pre-emergence Atrazine 50% WP at 0.50 kg a.i ha^{-1} followed hand weeding at 30 DAS	4.83(23.33)	6.20(38.00)	11.96(143.30)	11.64(134.97)	9.17	28.27
T_{10}: Weed free	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	100	100
T_{11}: Weedy check (control)	6.47(41.33)	6.48(41.67)	12.56(157.77)	13.72(188.17)	-	-
SEd	0.26	0.44	0.72	0.44		
CD (P = 0.05)	0.47	0.80	1.31	0.79		

Data in parenthesis are original values, which were transformed to $(\sqrt{x + 0.5})$ and analysed statistically.

Table 2: Residual effect of extreme levels of atrazine administered in *Kharif* maize on growth parameters of succeeding cowpea.

Treatments	Germination percentage (%)		At harvest			
			Plant height (cm)		Plant dry weight (g $plant^{-1}$)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1: Pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1}	85.33	79.24	69.93	94.80	24.93	10.49
T_2: Pre-emergence atrazine 50% WP at 0.75 kg a.i ha^{-1}	87.67	75.91	78.87	93.40	25.80	15.60
T_3: Pre-emergence atrazine 50% WP at 1.00 kg a.i ha^{-1}	87.00	76.10	78.93	91.33	15.87	13.49
T_4: Pre-emergence atrazine 50% WP at 1.25 kg a.i ha^{-1}	79.00	75.76	85.00	85.17	13.97	16.08
T_5: Pre-emergence atrazine 50% WP at 1.50 kg a.i ha^{-1}	87.67	84.82	87.20	90.53	19.40	14.53
T_6: Pre-emergence atrazine 50% WP at 1.75 kg a.i ha^{-1}	88.00	78.64	92.13	91.97	23.50	17.57
T_7: Pre-emergence atrazine 50% WP at 2.00 kg a.i ha^{-1}	80.33	76.70	81.27	98.70	18.03	18.55
T_8: Pre-emergence atrazine 50% WP at 0.50 kg a.i ha^{-1} followed by Tembotrione at 120 g a.i ha^{-1} as post-emergence at 25 DAS	84.33	87.57	92.37	96.57	26.67	18.51
T_9: Pre-emergence Atrazine 50 % WP at 0.50 kg a.i ha^{-1} followed by hand weeding at 30 DAS	77.00	75.37	69.87	83.03	13.37	9.97
T_{10}: Weed free	76.67	78.94	95.90	109.90	28.33	24.62
T_{11}: Weedy check (control)	82.67	82.12	69.60	82.67	8.70	9.30
SEd	6.25	6.75	13.05	6.69	9.86	3.19
CD (P = 0.05)	NS	NS	NS	12.12	NS	5.79

Letters NS in the table indicate that the data is not significant.

Table 3: Residual effect of extreme levels of atrazine imposed in *Kharif* maize on yield attributes and yield of succeeding cowpea.

Treatment	No. of pods plant^{-1}		100-seed weight (g)		Seed yield (kg ha^{-1})		Haulm yield (kg ha^{-1})		Harvest index	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	2.00	2.33	4.40	3.90	13.67	2.00	2932.33	2037.00	0.00	0.00
T_2	4.00	1.67	4.97	3.90	20.00	6.33	2191.33	1944.33	0.01	0.00
T_3	4.00	2.33	5.27	4.87	46.33	1.67	2654.33	1852.00	0.01	0.00
T_4	4.00	2.33	6.50	3.43	66.33	9.00	2685.00	2160.33	0.02	0.00
T_5	3.00	3.33	7.87	4.77	49.33	3.67	21.60.67	2222.33	0.01	0.00
T_6	3.67	3.00	7.83	4.27	108.00	24.33	2253.00	2253.00	0.04	0.01
T_7	5.00	6.33	7.93	5.77	123.33	100.00	3024.67	3241.00	0.04	0.03
T_8	5.67	3.00	9.73	5.57	200.67	49.00	3271.67	2561.67	0.06	0.02
T_9	2.67	2.67	7.43	4.27	51.67	14.67	2284.00	2253.00	0.02	0.01
T_{10}	14.67	13.00	9.93	10.93	788.67	842.33	3364.33	5031.00	0.19	0.15
T_{11}	1.67	1.00	3.83	3.43	4.67	1.00	2160.33	1450.67	0.00	0.00
SEd	2.20	2.80	2.98	3.22	48.73	43.68	541.38	564.90	0.02	0.01
CD (0.05)	3.98	5.07	NS	NS	88.31	79.17	NS	1023.82	0.03	0.02

Letters NS in the table indicate that the data is not significant.

kg a.i ha^{-1} followed by hand weeding at 30 DAS (T_9). During *rabi* 2020-21 it was recorded in PE atrazine at 2.00 kg a.i ha^{-1} (T_7) (5.03/m^2) which was at par with T_2, T_3, T_4, T_5, T_6 and T_8. Similar trend was observed with total weed dry weight. Amid *rabi* 2019-20, T_8 recorded the lower total weed dry weight (9.81 g m^{-2}) and it was at par with T_2, T_3, T_4 and T_7 while during 2020-21, T_7 registered the lower total weed dry weight (10.68 g m^{-2}) and it was at par with T_8. Lower total weed dry weight might be due to lower total weed density registered in these treatments. The results are not in agreement with the findings obtained by Mutsvandiani *et al*. (2015) who reported that weed biomass was not affected by the residual atrazine. Nonetheless, Rani *et al*. (2021) also reported a decreased total weed density and dry matter in green gram due to residual effect of weed management practices imposed in preceding maize.

Weed control efficiency (WCE)

Residual effect of PE atrazine at 0.50 kg a.i ha^{-1} followed by Tembotrione at 120 g a.i ha^{-1} as post-emergence at 25 DAS (T_8) recorded the highest WCE (39.25%) at harvest during *rabi* 2019-20 while amid *rabi* 2020-21, it was registered under residual effect of PE atrazine at 2.00 kg a.i ha^{-1} (T_7) with mean value of 39.65% (Table 1). Higher WCE in these treatments might be owing to reduction in weed growth and density. The results confirm earlier report by Bommayasamy and Chinnamuthu (2021).

Residual effect on succeeding cowpea

Plant growth parameters

Residual effect of extreme levels of atrazine did not show any significant difference on germination of cowpea during both *rabi* seasons. Plant height and plant dry weight were not significantly influenced by treatments at harvest during *rabi* 2019-20. In contrast, amid *rabi* 2020-21, both parameters were significantly affected (Table 2). Highest plant height (109.90 cm) and plant dry weight (24.62 g) were recorded under weed free (T_{10}) and it was at par with T_7 and T_8 regarding both parameters. This might be owing to better control of weeds which in turn might lead to low weed density and biomass of weeds in these treatments which favoured the cowpea to acquire all the vital resources needed for crop growth and development (Rani *et al*. 2021).

Yield attributes and yield

Number of pods plant^{-1}, seed yield and harvest index (HI) were significantly influenced by treatments during both *rabi* seasons whereas haulm yield was only affected during *rabi* 2020-21 (Table 3). The highest number of pods plant^{-1} (14.67 and 13.00), seed yield (788.67 and 842.33 kg ha^{-1}) and harvest index (0.19 and 0.15) was recorded in weed free (T_{10}) during *rabi* 2019-20 and 2020-21 respectively. This might be chiefly due to minimum crop-weed competition throughout the growing period of cowpea, which enhanced more synthesis and translocation of assimilates to developing pods and seeds (Rani *et al*. 2021). Concerning haulm yield during *rabi* 2020-21, T_{10} continued to show its predominance as it registered highest haulm yield (5031 kg ha^{-1}). There was no significant difference between treatments with reference to 100-seed weight. Seed test weight is a genetic character of plant and does not change with management practices (Bommayasamy and Chinnamuthu, 2021).

CONCLUSION

It is clear from the results obtained from this study that, residual effect of extreme levels of atrazine imposed in *Kharif* maize has drastically failed to effectively control weeds during *rabi* seasons. This is evidently shown by lower weed control efficiency (below 50%) recorded in all herbicidal treatments. This has led to increased weed growth and density in these treatments which resulted to lower yield attributes of cowpea and finally to lower yield. Highest number of pods plant^{-1}, seed yield, haulm yield, and harvest index of succeeding cowpea were noticed in weed free treatment indicating that it is vital to keep the field from weeds during the growing period of a crop in order to get maximum yield.

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