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Weed and Nutrient Dynamics in Maize as Influenced by different Weed Management Practices

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ABSTRACT: The steadily increasing cost of manual weeding has increased the need for chemical weed control and the main concern is in finding a better herbicide that can outperform even manual weeding. A field study conducted during *Kharif* 2017 on the sandy loam soil of Bangalore to study the weed dynamics, maize yield, and nutrient uptake under different post-emergence herbicide treatments. Significantly lower density and dry matter of weeds was recorded with passing cycle weeder followed by hand weeding at 20 and 35 DAS followed by ready mix application of topramezone + dimethanamid-p at 570 g ha^{-1} at 20 DAS and tembotrione at 120 g ha^{-1} + stefesmero adjuvant at 2 ml L^{-1} of water at 20 DAS. Passing cycle weeder followed by hand weeding at 20 and 35 DAS recorded the lowest uptake of N, P and K by weeds and the highest uptake of N, P and K by maize crop followed by ready-mix application of topramezone + dimethanamid-p at 570 g ha^{-1} at 20 DAS and tembotrione at 120 g ha^{-1} + stefesmero adjuvant at 2 ml L^{-1} of water at 20 DAS.

Keywords: Topramezone, Tembotrione, Dimethanamid-p, Nutrient dynamics and Nutrient uptake.

INTRODUCTION

Maize (*Zea mays* L.) also known as corn is one in all the foremost necessary cereal crops within the world agricultural economy as food, feed and industrial merchandise. It is a miracle C_4 crop that has a very high yield potential and ranks first among cereals followed by rice, wheat and millets in productivity. There is no other alternative cereal, which has such an immense potentiality and thus rightly called 'Queen of Cereals'

Weeds are serious problem in maize, particularly in irrigated areas and assured rainfed situations during monsoon season where there is adequate moisture throughout the crop growth period. In addition to this heavy fertilization, wider spacing and slower initial growth, makes maize susceptible to weed competition. Weeds compete with crop plants for nutrients, moisture, space and light and reduce not only the crop yields but also quality of produce. In maize the extent of yield reduction due to weeds is in a range of 33 to 55 per cent depending upon factors like type of weed flora and its density in standing crop (Sharma *et al*. 2000). So, timely weed management is essential for achieving higher yield. In maize, initial 0-60 DAS is critical for crop weed completion for better crop growth and productivity (Girsang and Wibowo, 2018).

However, weed management by hand weeding has become unfeasible due to a lack of human labour and increasing wages. Herbicides are the greatest alternative for weed control in such circumstances. Furthermore, in India, usage of herbicides has revolutionized weed management practices in rice, wheat, maize, and use of herbicides for weed management in maize is quite effective to manage the composite weed flora. At present, Atrazine is the most widely recommended pre-emergence herbicide for weed management in maize. There is also a need of post-emergence herbicides for management of weeds which occur at 15-25 days of crop and offer severe competition for growth resources, thereby lowering the productivity of maize (Sreelatha *et al*., 2020).

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 2017 under AICRP on weed management, Main Research

Station, University of Agricultural Sciences, Hebbal, Bangalore. The experiment was laid out in a randomized block design with nine treatments and three replications. The treatments were atrazine at 1250 g ha^{-1} at 3 DAS, tembotrione at 120 g ha^{-1} + stefesmero adjuvant @ 2 ml L^{-1} of water at 20 DAS, topramezone + dimethanamid-p at 570 g ha^{-1} at 20 DAS, topramezone at 25.2 g ha^{-1} at 20 DAS, dimethanamid-p at 600 g ha^{-1} at 20 DAS, 2,4-D-sodium salt at 500 g ha^{-1} at 20 DAS, halosulfuron-methyl + atrazine at 596 g ha^{-1} at 20 DAS, cycle weeder followed by hand weeding at 20 and 35 DAS and unweeded control. The herbicides were applied using spray volume of 750 L ha^{-1} for pre-emergence and 500 L ha^{-1} for post-emergence with knapsack sprayer having flood -jet nozzle.

The soil of the experimental site was sandy loam with a pH of 6.28, low in available N (252.7 kg ha^{-1}), medium in available phosphorus (23.5 kg ha^{-1}) and available potassium (268.4 kg ha^{-1}). Maize hybrid '*BRMH-1*' was sown with a spacing of 60 × 30 cm and the recommended dose of fertilizer *i.e*., 150-75-40 kg of N, P and K was applied with two splits of nitrogen. Observations on weed density and weed dry matter were recorded in an area of 0.25 m^2 and converted to 1 m^2.

The nutrient content in soil were analyzed as suggested by Subbiah and Asija (1956) for N, Olsen's method for P and neutral normal ammonium acetate method for K (Jackson 1973). Total N, P and K uptake by the plant and weed samples was calculated by using the following formula:

Nutrient uptake (kg/ha) =

$$\frac{\text{Nutrient concentration (\%)}}{100} \times \text{biomass (kg/ha)}$$

The data on weed density (no. m^{-2}) and weed dry weight (g m^{-2}) were transformed by using square root ($\sqrt{x+1}$) transformation when the data consists of small whole numbers and log (x+2) transformation when the data of whole numbers cover a wide range of values as suggested by Gomez and Gomez (1984). The transformed data were subjected to Fisher's method of "Analysis of Variance" (ANOVA) as outlined by Panse and Sukhatme (1954). Wherever F- test was significant, for comparison between the treatment means, an appropriate value of least significant difference (LSD) was worked out. All the data were analyzed and the results are presented and discussed at a probability level of 5%.

RESULTS AND DISCUSSION

Weed flora. Major weed flora observed in the experimental plots were *Cyperus rotundus* (sedge), *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Digitaria marginata*, *Echinochloa colona*, *Eleusine indica* (among grasses), *Ageratum conyzoides*, *Alternanthera sessilis*, *Amaranthus viridis*, *Borreria hispida*, *Commelina benghalensis*, *Euphorbia hirta*, and *Legascea mollis* (among broad-leaved weeds). Among the weed species, the densities of *Cyperus rotundus*, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Digitaria marginata*, *Ageratum conyzoides*, *Borreria articularis*, *Commelina benghalensis*, *Euphorbia hirta* were more than other weed species indicating their dominance and competitiveness with the maize crop (Table 1).

Weed dynamics. Significantly lower sedge density and dry weight (9.3 m^{-2} and 1.33 g m^{-2} at 30 DAS; 26 m^{-2} and 23.2 g m^{-2} at harvest, respectively) was observed in post-emergence application of halosulfuron-methyl + atrazine 596.3 g ha^{-1} at 20 DAS compared to other treatments (Table 2). This finding corroborated with the findings of Chinnusamy *et al.* (2012) in which application of halosulfuron-methyl significantly controlled *Cyperus rotundus* in sugarcane. With respect to grasses, significantly lower density and dry weight (11.3 g m^{-2} and 5.33 g m^{-2} at 30 DAS, 29.3 g m^{-2} and 25.2 g m^{-2} at harvest, respectively) was recorded with application of topramezone + dimethanamid-p at 570 g ha^{-1} at 20 DAS compared to other treatments.

Table 1: Species wise major weed flora (no./m^2) observed in maize at harvest as influenced by weed management practices.

Treatments	Sedge	Grasses					Broad leaf weeds					Total weeds
	Cr	Cd	Da	Dm	Ei	Total	Ac	Ba	Cb	Eh	Total	
Atrazine 1250 g ha^{-1} at 3 DAS	**36.0**	**11.7**	**5.7**	**13.3**	**4.7**	**48.3**	**12.0**	**6.0**	**8.0**	**10.3**	**54.3**	**138.7**
Tembotrione 120 g ha^{-1} + stefesmero adjuvant 2 ml L^{-1} of water at 20 DAS	35.3	10.7	4.0	16.0	5.3	40.7	10.0	5.0	10.0	8.0	50.0	126.0
Topramezone + dimethanamid-p 570 g ha^{-1} at 20 DAS	26.7	8.7	5.3	11.3	1.3	29.3	12.7	3.0	8.7	9.3	46.7	102.7
Topramezone 25.2 g ha^{-1} at 20 DAS	36.0	8.7	6.6	25.3	6.7	58.7	7.3	6.7	12.0	8.0	61.7	156.3
Dimethanamid-p 600 g ha^{-1} at 20 DAS	35.3	12.0	7.3	20.7	6.3	57.3	11.3	7.7	8.0	10.0	63.7	156.3
2,4-D-sodium salt 500 g ha^{-1} at 20 DAS	27.0	11.3	14.7	21.3	8.0	82.7	8.0	2.7	4.7	10.7	44.0	157.0
Halosulfuron-methyl + atrazine 596 g ha^{-1} at 20 DAS	26.0	16.0	10.6	15.3	16.0	66.7	15.0	5.3	7.3	6.7	67.3	160.0
Passing cycle weeder *fb* HW at 20 and 35 DAS	22.7	8.7	5.3	9.3	0.0	26.0	10.7	4.7	8.7	2.0	42.3	91.0
Unweeded control	42.0	11.3	16.7	26.0	18.7	81.3	23.3	16.7	12.0	6.7	75.0	198.3

Sedge- Cr=*Cyperus rotundus;* Grasses- Cd=*Cynodon dactylon,* Da=*Dactyloctenium aegyptium,* Dm=*Digitaria marginata,* Ei=*Eleusine indica;* Broad leaf weeds- Ac=*Ageratum conyzoides,* Ba=*Borreria articularis,* Cb=*Commelina benghalensis,* Eh=*Euphorbia hirta.*
Note: Total weed count includes the density of minor weeds also which are not included in the table

These findings are in accordance with Nader *et al.* (2011). The broad-leaf weeds density and dry weight (8.0 m^{-2} and 1.33 g m^{-2} at 30 DAS; 44.0 m^{-2} and 24.8 g m^{-2} at harvest, respectively) was significantly lower in application of 2,4-D-sodium salt 500 g ha^{-1} at 20 DAS compared to other treatments.

At both 30 DAS and at harvest the density and dry weight of total weeds among herbicide treatments was observed to be the lowest with the treatment involving application of topramezone + dimethanamid-p 570 g ha^{-1} at 20 DAS due to control of broad-spectrum weeds as a result of different mode of action of herbicides *i.e.*, topramezone inhibited the HPPD enzyme (4-hydroxyphenylpyruvate dioxygenase), which play a major role in carotenoid biosynthetic pathway. As a result, oxidative degradation of chlorophyll occurs, leading to pronounced whitening or bleaching of sensitive grasses and broad leaf weeds. Dimethanamid is a shoot inhibiting herbicide which can affect multiple sites within a plant but primarily interfering with lipid and protein synthesis and finally resulting in death of the sensitive sedge, grasses and broad leaf weeds (Pradeep *et al.*, 2017). The second-best treatment in reducing the total weed density and dry weight was tembotrione 120 g ha^{-1} + stefesmero adjuvant 2 ml L^{-1} of water due to inhibition of HPPD enzyme in grasses and broad leaf weeds. The next best treatment was pre-emergence application of atrazine 50% WP at 1250 g ha^{-1} due to better control of grasses and broad leaf weeds. The results are in agreement with the reports of Schulte and Kocher (2009); Kumar *et al.* (2017); Sharma *et al.*, (2000).

Table 2: Category wise weed density, weed dry weight and weed control efficiency (WCE) at 30 DAS and at harvest in maize as influenced by weed management practices.

Treatment	Weed density (no. m^{-2})				Weed dry weight (g m^{-2})				WCE (%)
	Sedge⁺	Grasses#	Broad-leaf weeds⁺	Total#	Sedge⁺	Grasses⁺	Broad-leaf weeds⁺	Total#	
30 DAS									
Atrazine 1250 g ha^{-1} at 3 DAS	4.42 (18.7)	1.18 (13.3)	4.02 (15.3)	1.69 (47.3)	2.96 (7.83)	2.91 (7.50)	1.98 (2.93)	1.30 (18.3)	66.4
Tembotrione 120 g ha^{-1} + stefesmero adjuvant 2 ml L^{-1} of water at 20 DAS	4.35 (18.0)	1.20 (14.0)	3.82 (14.7)	1.67 (46.7)	2.77 (6.83)	2.97 (7.83)	1.93 (2.80)	1.28 (17.5)	67.9
Topramezone + dimethanamid-p 570 g ha^{-1} at 20 DAS	3.40 (10.7)	1.12 (11.3)	3.95 (14.7)	1.58 (36.7)	1.69 (1.87)	2.46 (5.33)	1.92 (2.73)	1.05 (9.94)	81.7
Topramezone 25.2 g ha^{-1} at 20 DAS	4.39 (18.7)	1.30 (18.0)	3.58 (12.0)	1.70 (48.7)	2.57 (5.67)	3.17 (9.10)	1.92 (2.87)	1.28 (17.6)	67.6
Dimethanamid-p 600 g ha^{-1} at 20 DAS	3.85 (14.0)	1.20 (14.7)	4.49 (19.3)	1.69 (48.0)	1.81 (2.30)	2.97 (7.87)	2.93 (7.70)	1.29 (17.9)	67.2
2,4-D-sodium salt 500 g ha^{-1} at 20 DAS	3.31 (10.0)	1.53 (35.3)	2.99 (8.0)	1.73 (53.3)	1.57 (1.47)	5.07 (24.9)	1.52 (1.33)	1.47 (27.7)	49.2
Halosulfuron-methyl + atrazine 596 g ha^{-1} at 20 DAS	3.17 (9.3)	1.37 (22.0)	4.71 (21.3)	1.73 (52.7)	1.53 (1.33)	3.30 (10.0)	3.30 (9.97)	1.36 (21.3)	60.9
Passing cycle weeder *fb* HW at 20 and 35 DAS	2.85 (7.3)	0.88 (6.0)	3.20 (9.3)	1.38 (22.7)	1.37 (0.87)	1.30 (0.70)	1.55 (1.40)	0.69 (2.97)	94.5
Unweeded control	4.79 (22.0)	1.62 (40.0)	5.62 (30.7)	1.97 (92.7)	3.66 (12.4)	5.16 (25.8)	4.14 (16.3)	1.75 (54.4)	0.0
LSD (p=0.05)	0.89	0.23	1.05	0.11	0.44	0.66	0.58	0.24	
At harvest									
Atrazine 1250 g ha^{-1} at 3 DAS	6.07 (36.0)	1.70 (48.3)	1.74 (54.3)	2.14 (138.7)	5.44 (28.8)	1.59 (37.1)	1.53 (32.1)	1.99 (98.0)	52.9
Tembotrione 120 g ha^{-1} + stefesmero adjuvant 2 ml L^{-1} of water at 20 DAS	6.00 (35.3)	1.62 (40.7)	1.69 (50.0)	2.09 (126.0)	5.39 (28.3)	1.55 (35.2)	1.51 (31.9)	1.98 (95.3)	54.2
Topramezone + dimethanamid-p 570 g ha^{-1} at 20 DAS	5.21 (26.7)	1.49 (29.3)	1.67 (46.7)	2.01 (102.7)	4.96 (23.8)	1.43 (25.2)	1.43 (25.3)	1.88 (74.3)	64.3
Topramezone 25.2 g ha^{-1} at 20 DAS	6.07 (36.0)	1.78 (58.7)	1.79 (61.7)	2.19 (156.3)	5.65 (31.1)	1.61 (38.7)	1.53 (33.3)	2.01 (103.2)	50.4
Dimethanamid-p 600 g ha^{-1} at 20 DAS	6.01 (35.3)	1.77 (57.3)	1.81 (63.7)	2.19 (156.3)	5.76 (32.5)	1.61 (39.1)	1.55 (34.7)	2.02 (106.2)	49.0
2,4-D-sodium salt 500 g ha^{-1} at 20 DAS	5.58 (27.0)	1.92 (82.7)	1.65 (44.0)	2.19 (157.0)	5.27 (27.1)	1.86 (72.9)	1.41 (24.8)	2.09 (124.9)	40.0
Halosulfuron-methyl + atrazine 596 g ha^{-1} at 20 DAS	5.19 (26.0)	1.83 (66.7)	1.82 (67.3)	2.20 (160.0)	4.91 (23.2)	1.74 (53.7)	1.61 (40.9)	2.07 (117.7)	43.4
Passing cycle weeder *fb* HW at 20 and 35 DAS	4.81 (22.7)	1.44 (26.0)	1.62 (42.3)	1.95 (91.0)	4.78 (22.1)	1.41 (24.3)	1.37 (22.5)	1.84 (68.9)	66.9
Unweeded control	6.54 (42.0)	1.91 (81.3)	1.88 (75.0)	2.29 (198.3)	7.34 (53.2)	1.85 (71.8)	1.91 (83.2)	2.31 (208.2)	0.0
LSD (p=0.05)	0.78	0.17	0.09	0.05	0.47	0.16	0.11	0.09	

Data within parentheses are original values; **#** - data analyzed using log (x+2) transformation, + - square root (√x+1) transformation

Weed control efficiency. The data on weed control efficiency as influenced by weed management practices are presented in Table 2. At 30 DAS and at harvest highest weed control efficiency was recorded in passing cycle weeder followed by hand weeding at 20 and 35 DAS (94.5 and 66.9%, respectively) due to highest efficiency of human labour in removing all the types of weeds.

Among herbicide treatments, highest weed control efficiency at 30 DAS and at harvest was recorded in post-emergence application of topramezone + dimethanamid-p 570 g ha^{-1} (81.7 and 64.3%, respectively) due to control of broad spectrum of weeds including sedge, grasses and broad-leaf weeds and lowest weed control efficiency was recorded in 2,4-D-sodium salt 500 g ha^{-1} (49.2 and 40.0%, respectively) due to control of only some specific weed flora like broad-leaf weeds more efficiently, sedge to some extent and no control of grassy weeds.

Nutrient uptake and yield. At harvest, (Table 3) among herbicide treatments, topramezone + dimethanamid-p 570 g ha^{-1} at 20 DAS recorded higher uptake of nitrogen, phosphorus and potassium (119.33, 29.54 and 95.65 kg ha^{-1} at harvest, respectively) by maize crop compared to other herbicide treatments except tembotrione 120 g ha^{-1} + stefesmero adjuvant 2 ml L^{-1} of water at 20 DAS (111.7, 27.56 and 92.83 kg ha^{-1} at harvest, respectively) and atrazine 1250 g ha^{-1} at 3 DAS (106.57, 26.81 and 89.54 kg ha^{-1} at harvest, respectively) with which it was on par. Whereas the nutrient removal by weeds is in the reverse order as that of nutrient uptake by crop *i.e*., lowest in topramezone + dimethanamid-p followed by tembotrione and atrazine among herbicide treatments.

There is a positive correlation between nutrient uptake by crops and yield. Similarly, there is a negative correlation between nutrient removal by weeds and yield. Hence kernel yields will be higher whenever the nutrient uptake by crop is higher and nutrient removal by weeds is lower. Among different treatments, nitrogen, phosphorus and potassium uptake by maize crop at 30 DAS and at harvest was significantly higher in passing cycle weeder followed by hand weeding at 20 and 35 DAS because of which it has recorded a highest yield of (6.56 t ha^{-1}) which was on par with herbicide treatments, topramezone + dimethanamid-p 570 g/ha at 20 DAS (6.40 t ha^{-1}) and tembotrione 120 g ha^{-1} + stefesmero adjuvant 2 ml L^{-1} of water at 20 DAS (6.20 t ha^{-1}) as a result of better weed control and less weed competition. Whereas, the lowest uptake of nitrogen, phosphorus and potassium by maize crop and highest removal of nitrogen, phosphorus and potassium by weeds was recorded in unweeded control as a result of weed competition resulting in lower maize yield of 2.93 t ha^{-1}. The results are in accordance with Sinha *et al*., (2005); Rani *et al*., (2021).

Table 3: Effect of weed management practices on maize kernel yield, nutrient uptake by weeds and maize at harvest.

Treatment	Maize kernel yield (t ha^{-1})	Nutrient uptake (kg ha^{-1})					
		Weeds			Maize		
		N	P	K	N	P	K
Atrazine 1250 g ha^{-1} at 3 DAS	5.78	34.10	21.10	26.65	106.57	26.81	89.54
Tembotrione 120 g ha^{-1} + stefesmero adjuvant 2 ml L^{-1} of water at 20 DAS	6.20	28.87	18.10	21.18	111.70	27.56	92.83
Topramezone + dimethanamid-p 570 g ha^{-1} at 20 DAS	6.40	23.40	14.60	15.12	119.33	29.54	95.65
Topramezone 25.2 g ha^{-1} at 20 DAS	5.33	41.94	25.40	33.94	100.82	25.16	84.92
Dimethanamid-p 600 g ha^{-1} at 20 DAS	5.13	49.30	27.90	37.28	95.36	25.06	82.94
2,4-D-sodium salt 500 g ha^{-1} at 20 DAS	5.03	59.94	31.10	49.78	86.66	22.07	75.53
Halosulfuron-methyl + atrazine 596 g ha^{-1} at 20 DAS	5.09	55.52	29.90	42.16	91.20	23.89	80.82
Passing cycle weeder *fb* HW at 20 and 35 DAS	6.56	19.25	11.60	12.94	123.80	30.94	98.68
Unweeded control	2.93	98.71	37.84	78.66	62.01	15.53	44.36
LSD (p=0.05)	0.58	7.23	3.94	6.71	19.20	4.37	12.65

DAS-Days after sowing.

Weeds are the silent robbers of nutrients and deplete the soil nutrients rapidly than the crop. Hence, the soil with higher population of weeds will have lower soil fertility levels when compared to an exhaustive crop. Poor soil nutrient status was recorded with unweeded control (176.5, 17.77 and 133.6 kg ha^{-1}, respectively) due to high weed density and dry weight. Higher soil nutrient status was recorded in passing cycle weeder followed by hand weeding at 20 and 35 DAS (225.4, 34.18 and 174.3 kg ha^{-1}, respectively) followed by other herbicide treatments. Among herbicide treatments topramezone + dimethanamid-p 570 g ha^{-1} at 20 DAS (220.5, 31.63 and 170.1 kg ha^{-1}, respectively) and tembotrione 120 g ha^{-1} + stefesmero adjuvant 2 ml L^{-1} of water at 20 DAS (214.7, 28.92 and 166.0 kg ha^{-1}, respectively) were superior than other treatments.

CONCLUSION

According to the results of the current study, all of the herbicides tested in the current investigation reduced weeds and increased maize production when compared to the unweeded control. Post-emergence application of topramezone + dimethanamid-p 570 g ha^{-1} at 20 DAS was highly effective in providing broad spectrum weed control in maize along with getting higher yield which is comparable to that of hand weeding. As chemical weed control alone doesn't contribute to long term sustainability, the herbicide compatibility in integrated weed management should be tested in further studies.

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