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Physiological response of post emergence application of herbicides in maize [*Zea mays* (L.)]

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Abstract
A field experiment entitled was conducted at Research Farm, AICRP on Forage Crops, Department of Agronomy and Plant Physiology, JNKVV, Jabalpur (Madhya Pradesh) during *Kharif* season of the year 2018-19. The treatments comprised of 7 weeds control methods *viz*. application of herbicides Tembotrione @120g ha^{-1}, Topramezon @35g ha^{-1}, Tembotrione+Atrazine @120g+250g ha^{-1}, Topramezon+Atrazine @35g+250g ha^{-1}, 2,4-D @500g ha^{-1}, two hand weeding, and another one kept untreated (weedy check) in each replication. The research experiment was laid out in a randomized blockdesign replicated thrice. The highest total dry weight was recorded in treatment T_6- (Hand weeding) and T_6 alsohad highest magnitude of most of the physiological parameters i.e. LAI (3.27), LAD (69353.77), CGR (0.083) and SLW (0.00738) whereas, maximum value of average RGR (0.098), NAR (0.00165) and SLA (213.90) recorded in treatment T_7- Control (weedy check). The major yield components were also found superior for number of cobs plant^{-1}, cob length, cob girth, number of grains cob^{-1}, cob weight, 100 grain weight including high biological yield and seed yield and highest harvest index in the hand weeding treatment (T_6) due to better control of weeds which resulted into better photo assimilate transportation towards the sink. It is also concluded from the economic analysis. The herbicidal treatment Topramezon+Atrazine @35+250g ha^{-1} was found superior in benefit: cost ratio and economic as compared to other treatments.

Keywords: Physiological, response, emergence, herbicides, *Zea mays* L.

1. Introduction
Maize (*Zea mays* L) is one of the most important cereal crop in the world agricultural economy after wheat and rice. Maize is dual purpose crop cultivated for food grain and animal fodder. As per first advance estimate published by ministry of agriculture and farm welfare on 26 September 2018, In India it is cultivated on an area of 8.7 million ha with 21.47 million tonnes production and 2509.02 kg ha^{-1} productivity (MoA and FW, GOI). In Madhya Pradesh the total area of maize was 1524.0 ha with the production of 2350 tonnes (Ministry of Agriculture, Annonymous. 2016) [3]. Maize (*Zea mays* L.) is an annual grass belongs to familypoaceae with chromosome number (2n=2x=20). Maize has been domesticated as a crop about 10000 years ago, originating in Central America (Maxico).
Maize is C4 plant. In bright sunlight and warm temperature maize plant grow faster than other plants. C4 plants use C4 carbon fixation pathways which increase their photosynthetic efficiency by suppressing photorespiration. Maize is very sensitive to weed infestation that usually causes severe yield reduction especially in dry land conditions (Sulewska *et al*., 2012) [18]. In maize crop maximum crop weed competition was during the period of two to six weeks after sowing (Sandhu and Gill (1973)) [14]. If weeding is delayed during this period, yield attributes may be irreversibly damaged. So it was well established that first 30 days after sowing was critical period of weed competition in maize (Krishnamurthy *et al*. 1981) [9].
Weeds emergence and weed growth was rapidly then crop, significant crop-weed competition for various resources *viz*., available nutrients, moisture, sunlight and space during entire vegetative and early reproductive stages of maize. Weeds reduces the photosynthetic efficiency, dry matter production and distribution to economical parts and there by reduces sink capacity of crop resulting in poor grain yield. Thus, weed control in maize is absolutely necessary and is mainly based on chemical method. Weed control was very important practices in maize crop because weeds can significantly decrease the grain yield in maize which may

result to economic loss (Quee *et al*. 2016) [12]. Weeds occurrence in maize causes significant yield losses with an average of more than 29% in case of no weed control and more than12% despite weed control applications (Isik *et al*. 2006) [7].

Tembotrione is a new selective post-emergence herbicide forthe control of broadleaf and grassy weeds in maize. It inhibits 4-hydroxyphenylpyruvate dioxygenase (HPPD) enzyme, which converts tyrosine to plastoquinone and α-tocopherol, by this process biosynthesis of chlorophyll molecule and membrane structure is disrupted as a consequence of failure to properly assemble photosynthetic units and thus they control weeds and it is more effective in newly developing tissues that emerge bleached (Schulte and Kocher, 2009) [17]. Topramezone and tembotrione are the selective, post emergence herbicides that have been recently introduced for use in maize. These herbicides inhibit hydroxy-phenyl pyruvate di oxygenase (4-HPPD) and the biosynthesis of plastoquinone, with subsequent carotenoid pigment formation, membrane structure and chlorophyll disruption (Porter *et al*. 2005) [11].

2. Materials and Methods

The field experiment was conducted at Research Farm, All India Coordinated Research Project (AICRP) on Forage Crops, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh) during *Kharif* season 2018. Total seven treatments were laid out on well prepared seed bed INA randomized block design with three replications. The topography of the experimental field area was fairly uniform. All facilities including irrigation water were adequately available on the research farm to carry out the field experiment. The mean annual rainfall of the area is 1284 mm and nearly90% of the total annual rainfall is mainly received during the period between ends of June to end of September. The maximum and minimum temperature ranges between 24 °C to45 °C; and 20 °C to 32 °C, respectively within a year. In some of the years, maximum temperature reaches as high as 45 °C in the month of May or June, while minimum temperature falls down to a limit of 4.2 °Cduring end of December or January months. The relative humidity varies from season to season. It ranges between 80 to 90%during rainy season, which reduces as 60 to 75 and 20 to 40% during winter and summer seasons, respectively.

The observations were recorded on three randomly selected plants from each treatment and replication for the following parameters and per plant data was obtained by averaging the values. The phenological observations of maize crop were noted from three selected and tagged plants throughout the growth period through daily visual observations. Physiological growth parameters were recorded *viz*. Plant biomass and at its partitioning at 30, 60,90 DAS & at maturity stages, LAI, LAD, CGR, RGR, NAR, SLA, SLW, RWC and chlorophyll content index by Chlorophyll meter (CCM-200) were analysed during 30 to 100 days interval.

3. Results and Discussion

In this experiment, the LAI increased during advanced crop growth stage up to 75 DAS and declined thereafter, towards maturity. The reduction of LAI during later growth stages due to reduction of leaf magnitude of surface area as result of senescence in leaves of maize crop. The maximum average LAI (3.27) was recorded in treatment T6 (Hand weeding) followed by T4 (Topramizon + Atrazine @ 35g+250g ha-1). T7 control (weedy check) record minimum LAI. The maximum average LAD (69353.76) was recoded in treatment T6 (Hand weeding) as followed by treatment T4 (Topramizon + Atrazine @ 35g+250g ha-1). LAD increased during advanced crop growth stage up to 75 DAS and decline thereafter toward maturity. The reduced LAD during later phase of growth due to reduction of LAI. The close positive relationship was noted between dry matter yield with CGR, LAI, LAD the results are with close conformity with the findings of Zajac *et al*., (2005) [20].

The crop growth rate was increases up to 90 DAS very rapidly than, it was slow down due to maturity. The results are in conformity with the findings of Bisen and Sahu (2017) [4]. Raj *et al*. (2018) reported that pronounced improvement in crop growth rate (CGR) of maize was observed between 60-90 DAS and thereafter declined till harvest. The minimum average NAR (0.00157) exhibited in treatment T6 (Hand weeding at 20 and 40 DAS) and maximum average NAR (0.00165) had noted in control (Weedy check). Kaziu and Kashta (2018) [8] concluded that the increase in LAI and the increase in rate of dry matter accumulation, is directly proportional to rate of dry matter accumulation per unit leaf area (NAR).

The minimum average SLA (0162.55) exhibited in treatment T6 (Hand weeding at 20 and 40 DAS) and maximum average SLA (213.90) had noted in control (Weedy check).The relationship between SLA and SLW was considered reciprocal with each other because the increase in leaf area plant−1 and decrease in the leaf dry weight plant−1 increased the SLA; while increases in leaf dry weight plant−1 and reduction in leaf area plant−1 increased the SLW. These results are in close conformity with the findings of Amanullah, (2015) [2].

Leaf chlorophyll is a key indicator of leaf greenness, and it is often used to investigate leaf nutrient deficiencies and changes in chlorophyll (Ali *et al*. 2017) [1]. Chlorophyll content, LAI and leaf dry weight are positively influenced by fertilizer application, especially nitrogen (Hokmalipour & Darbandi, 2011) [6]. Hand weeding showed maximum chlorophyll content index (CCI) in all conclusive growth stages. CCI was increased with 70 DAS and thereafter, it declined. Miri (2009) [10] reported that chlorophyll content index (CCI) was significantly and positively correlated with grain yield and a harvest index of wheat in Iran. Schlemmer *et al*. (2005) [16] stated that drought stress had no significant effect on chlorophyll content of maize leaf and concluded that decrease in turger pressure caused by water deficit, resulted in change in amount of far red radiation passed through the leaf and this reason, read of chlorophyll meter device was changed. Relative water content is a resistant mechanism to drought, and that high relative water content is the result of more osmotic regulation or less elasticity of tissue cell wall (Ritchie *et al*. 1990) [13]. Drought stress making mechanisms inside the plant, leads to decrease in chlorophyll a but increase in chlorophyll b and total. Also leaf RWC was decreased as affected by drought (Hassanzadeh *et al*. 2009) [5]. The result indicated that the highest RWC (80.96) had exhibited in hand weeding followed by T4 and T3. The lowest RWC was recorded in control plots of maize crop.

The treatment T6-hand weeding at 20 and 40 DAS (27.76 g plant-1) & (2776.33 Kg ha-1) had significantly highest grain yield as well as biological yield among the treatments at par with T4-Topramizon+Atrazine @35g+250g ha-1 (25.17 g plant -1) & (2517.33 kg ha-1). T7- weedy check (12.8 g plant-1) & (1280.0 kg ha-1) recorded lowest grain yield in maize crop due to different herbicidal treatments. The present investigation also closely corroborates with the results of Sanodiya *et al*. (2013) [15] and Swetha *et al*., (2015) [19].

Table 1: Dry matter production and its partitioning (g plant^{-1}) at different growth stages in maize as influenced by various herbicidal treatments

Tr^{nt}	Dry weight at 30 days (g)			Dry weight at 60 days (g)			Dry weight at 90 days (g)					Dry weight at Maturity (g)				
No.	**Leaf**	**Stem**	**TDM**	**Leaf**	**Stem**	**TDM**	**Leaf**	**Stem**	**Cob**	**Tessal**	**TDM**	**Leaf**	**Stem**	**Cob**	**Tessal**	**TDM**
T1	0.77	0.458	1.23	22.53	55.57	78.43	68.33	142.60	81.83	17.87	334.50	51.77	126.07	128.30	12.43	310.97
T2	0.76	0.449	1.22	23.12	57.20	80.66	70.03	145.23	86.03	18.27	337.43	53.93	127.3	130.63	12.70	312.77
T3	1.14	0.630	1.78	29.10	60.57	90.00	73.93	147.80	93.90	20.37	345.76	54.02	131.27	134.47	14.07	325.37
T4	1.14	0.452	1.60	30.20	62.07	92.60	75.67	149.57	96.73	21.03	348.39	55.67	131.87	135.07	14.50	327.47
T5	0.71	0.425	1.14	21.90	54.37	76.27	69.07	141.23	80.13	17.17	323.25	51.90	125.87	127.27	12.20	309.60
T6	1.32	0.465	1.79	32.57	64.93	97.83	77.90	153.27	102.2	22.13	351.25	58.23	135.43	138.17	14.87	332.57
T7	0.50	0.324	0.83	19.7	49.73	70.77	62.77	131.47	72.03	13.30	308.18	45.48	116.17	109.83	11.70	292.37
S.Em ±	0.12	0.043	0.146	1.163	0.694	1.337	1.031	1.234	1.473	0.319	7.332	1.063	1.175	1.603	0.471	1.514
CD (At 5%)	0.36	0.134	0.450	3.585	2.139	4.121	3.178	3.804	4.539	0.985	22.59	3.276	3.621	4.940	1.453	4.667

Table 2: Leaf Area Index (LAI) and Leaf Area Duration (LAD) as influenced by various herbicidal treatments in maize crop 2018-2019

Treatment No.		LAI						LAD (cm^2. days)				
		30 DAS	**45DAS**	**60DAS**	**75DAS**	**90DAS**	**Average**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**	**Average**
T1	Tembotrione @ 120g ha^{-1}	0.301	1.783	3.703	4.78	4.404	2.993	15189.62	57489.125	93583.97	90326.72	64147.36
T2	Topramizon @ 120g ha^{-1}	0.311	1.824	3.874	4.888	4.537	3.087	15899.80	59101.35	95344.92	91800.45	65536.63
T3	Tembotrione+Atrazine @ 120g+250g ha^{-1}	0.404	1.907	3.928	5.036	4.679	3.190	17277.40	61330.77	97112.55	93862.15	67395.72
T4	Topramizon+Atrazine @35g+250g ha^{-1}	0.416	1.947	4.035	5.088	4.711	3.239	17962.25	62448	97763.25	93878.5	68013
T5	2, 4-D @500g ha^{-1}	0.273	1.685	3.572	4.690	4.308	2.905	14104.07	54571.5	90153.5	88746	61893.77
T6	Hand weeding (weed free)	0.446	2.0	4.043	5.130	4.781	3.279	20100.27	65248.37	98096.8	93969.6	69353.76
T7	Control (Weedy check)	0.229	1.36	3.096	4.387	4.028	2.619	12879.82	50368.8	84701.4	83579.1	57882.28
S.Em ±		0.0117	0.0351	0.0749	0.0461	0.0330	0.045	470.513	727.136	911.873	987.05	726.15
CD (At5%)		0.0360	0.1083	0.2307	0.1420	0.1017	0.1314	1449.79	2240.53	2809.76	3041.41	2157.51

Table 3: Growth analytical parameters CGR (g cm-2 day-1), RGR (g cm-2 day-1) and NAR (g cm^{-2} day^{-1}) in maize as influenced by various herbicide treatments

Treatments		CGR (g cm^{-2} day^{-1})			RGR (g cm^{-2} day^{-1})			NAR (g cm^{-2} day^{-1})		
		30-60 DAS	**60-90 DAS**	**Average**	**30-60 DAS**	**60-90 DAS**	**Average**	**30-60 DAS**	**60-90 DAS**	**Average**
T1	Tembotrione @ 120g ha^{-1}	0.0361	0.1154	0.0758	0.1396	0.0473	0.0934	0.00164	0.00147	0.00156
T2	Topramizon @ 120g ha^{-1}	0.0371	0.1156	0.0764	0.1381	0.0467	0.0924	0.00163	0.00145	0.00154
T3	Tembotrione+Atrazine @ 120g+250g ha^{-1}	0.0414	0.1207	0.0811	0.1361	0.0450	0.0906	0.00171	0.00147	0.00159
T4	Topramizon+Atrazine @35g+250g ha^{-1}	0.0424	0.1212	0.0818	0.1336	0.0445	0.0890	0.00173	0.00147	0.00160
T5	2, 4-D @500g ha^{-1}	0.0350	0.1137	0.074	0.1399	0.0477	0.0938	0.00167	0.00148	0.00158
T6	Hand weeding (weed free)	0.0438	0.1226	0.083	0.1316	0.0440	0.0878	0.00169	0.00146	0.00157
T7	Control (Weedy check)	0.0326	0.1107	0.0717	0.1475	0.0490	0.0982	0.00174	0.00156	0.00165
S.Em ±		0.0007	0.0021	0.0002	0.0029	0.0007	0.0017	0.0000	0.0000	0.0000
CD (AT5%)		0.0021	0.0064	0.0007	0.0088	0.0021	0.0060	0.0001	0.0001	0.0001

Table 4: Growth analytic parameters SLA (cm2 g-1), SLW (g cm-2), Chlorophyll Content Index (CCI) and RWC (%) as influenced by various herbicidal treatments in maize crop 2018-2019

Treatment		SLA (cm^2 g^{-1})			SLW (g cm^{-2})			Chlorophyll Content Index			RWC (%)
		30-60 DAS	**60-90 DAS**	**Average**	**30-60 DAS**	**60-90 DAS**	**Average**	**50 DAS**	**70 DAS**	**90 DAS**	**60 DAS**
T1	Tembotrione @ 120g ha^{-1}	237.24	170.72	203.98	0.00434	0.00832	0.00633	25.386	28.513	20.096	72.43
T2	Topramizon @ 120g ha^{-1}	243.19	169.76	206.47	0.00421	0.00837	0.00629	25.625	29.322	20.214	73.26
T3	Tembotrione+Atrazine @ 120g+250g ha^{-1}	198.14	145.07	171.61	0.00521	0.00894	0.00708	26.727	31.233	21.218	77.8
T4	Topramizon+Atrazine @35g+250g ha^{-1}	197.54	140.53	169.03	0.00525	0.00919	0.00722	27.480	33.294	21.443	77.56
T5	2, 4-D @500g ha^{-1}	237.63	168.16	202.89	0.00437	0.00843	0.00640	23.818	26.996	19.893	70.76
T6	Hand weeding (weed free)	191.32	133.78	162.55	0.00534	0.00942	0.00738	30.119	35.215	23.033	80.96
T7	Control (Weedy check)	256.81	170.99	213.90	0.00403	0.00824	0.00613	22.211	24.338	15.692	65.75
S.Em ±		13.1201	0.0003	5.701	6.0790	0.0002	5.701	1.1190	1.1433	0.8630	1.2446
CD (AT5%)		40.4271	0.0011	19.728	18.7314	0.0006	19.728	3.4479	3.5230	2.6591	3.8349

4. Conclusion

The present investigation concluded that two hand weeding at 20 DAS and 40 DAS had highest magnitude of most of the physiological parameters ie. LAI, LAD and CGR which are the valuable components of yield in maize crop. However, the highest chlorophyll content index and relative water. The major yield components were also found superior for number of cobs plant-1, cob length, cob girth, number of grains cob-1, cob weight, 100 grain weight including high biological yield and seed yield and highest harvest index in the hand weeding treatment (T6) due to better control of weeds which resulted into better photo assimilate transportation towards the sink. It is also concluded from the economic analysis. The herbicidal treatment Topramezon + Atrazine @35+250g ha-1 was found superior in benefit: cost ratio and economic as compared to other treatments. Therefore, Topramezon + Atrazine @35+250g ha-1 herbicide treatment was more beneficial to the farmers in maize crop.

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