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Response of post emergence application of herbicides on phenophases, yield, biochemical components and economic analysis of 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 block design replicated thrice. Plant height significantly increased due to weed control treatments. The highest plant height was noted in treatment T_6 hand weeding and lowest plant height in treatment T_7- Control (weedy check) The biochemical estimations viz., protein (%), fat (%), carbohydrate (%), fibre (%), ash (%) significantly influenced by weed control treatments. Treatment T_6-Hand weeding had maximum value of carbohydrate (69.33), fat (3.95), fibre (2.87), ash (2.64). Whereas, treatment T_4-Topramizon + Atrazine @35g+250g ha^{-1} found maximum value of protein (9.97). 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.

Keywords: genetic combining ability, specific combining ability, okra, variance, growth, yield, quality

Introduction
Maize (*Zea mays* L.) is an annual grass belongs to family poaceae with chromosome number (2n=2x=20). Maize has been domesticated as a crop about 10000 years ago, originating in Central America (Maxico). As a grain crop, maize has several unusual or even unique characteristics. Maize is a miracle crop. Maize is known as "Queen of cereals" due to its highest genetic yield potential among the cereals. Maize is C4 plant. In bright sunlight and warm temperature maize plant grow faster than other plants. C4 plants use C4 carbonfixation pathways which increase their photosynthetic efficiency by suppressing photorespiration. N Maize is very sensitive to weed infestation that usually causes severe yield reduction especially in dryland conditions (Sulewska *et al*., 2012) [21]. In maize crop maximum crop weed competition was during the period of two to six weeks after sowing (Sandhu and Gill (1973) [17]. 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) [12].

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) [6]. Maize (*Zea mays* L.) is an annual grass belongs to family poaceae with chromosome number (2n=2x=20). Maize has been domesticated as a crop about 10000 years ago, originating in Central America (Maxico).

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 andearly 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) [15]. 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) [10]

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) [20]. Topramezone and tembotrione are the selective, postemergence 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) [14].

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 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

The maize seeds were analyzed for the biochemical constituents as following: The ash content in the seed sample was estimated according to AOAC (1980) [1]. The fat content in the sample was estimated by pelican equipment socs plus based on principle of Soxhlet's extraction method as described in AOAC (1980) [1]. Total carbohydrates in the sample were estimated by the hydrolysis method as described in AOAC (1984) [2]. The nitrogen content was estimated by micro kjeldhal method (A.O.A.C., 1965) [3] as per method suggested by Gopalan *et al*. (1985). The cost involved and the returns obtained under different treatments is very important aspect for determining the overall advantages. It was worked out in terms of cost of cultivation, gross monetary return (GMR), net monetary return (NMR) and benefit: cost ratio (B:C ratio) to ascertain the economic viability of the treatments.

Results and Discussion

In this experiment, Phenology refers to the timing of major developmental events in the life of a crop is an important event in determining the economic yield and its adaptability. Treatment T_6- (Hand weeding) had noted early tassel initiation, cob emergence, silking and grain formation but late physiological maturity and field maturity. Hence T6- (Hand weeding) required maximum number of days to complete the reproductive phase.

All the weed control treatments significantly increased the dry weight in different growth phases. The highest total dry weight was recorded in treatment T_6- (Hand weeding) and minimum was noted in T_7 Control (weedy check). Dry matter production followed an increasing trend up to 90 DAS thereafter, declined up to maturity due to drying of photosynthetic area of leaf.Plant height significantly increased due to weed control treatments. The highest plant height was noted in treatment T_6 hand weeding and lowest plant height in treatment T_7- Control (weedy check).

Among the major yield attributing components viz; number of cobs plant^{-1}, cob length, cob girth, number of grains cob^{-1}, cob weight, 100 grain weight, seed yield, biological yield and harvest index were influenced by the weed control treatments. Number of cobs plant^{-1} (1.66), cob length (16.91), cob girth (4.10), number of grains cob^{-1} (322.22), cob weight (133.68), 100 grain weight (28.93), seed yield (27.76 g plant^{-1}), biological yield (197.42 g plant^{-1}) and harvest index (11.45) were significantly maximum in treatment T_6 hand weeding as compared to control (weedy check).

The economic analysis showed significant variability among the herbicidal treatments. Hand weeding showed maximum total cost of cultivation, gross monetary return and net return followed by treatment T_4 and T_3. Treatment T4- Topramizon + Atrazine @35g+250g ha^{-1} found maximum benefit: cost ratio among the treatments. Hence Treatment T4- Topramizon + Atrazine @35g+250g ha^{-1} was indicates best economically superior and profitable for farmer among the herbicidal treatments.

The biochemical estimations viz., protein (%), fat (%), carbohydrate (%), fibre (%), ash (%) significantly influenced by weed control treatments. Treatment T_6-Hand weeding had maximum value of carbohydrate (69.33), fat (3.95), fibre (2.87), ash (2.64). Whereas, treatment T_4-Topramizon + Atrazine @35g+250g ha^{-1} found maximum value of protein (9.97).

Conclusion

It is revealed from the present investigation that treatments were consisting of seven weed control treatments viz; Tembotrione @120g ha^{-1}, Topramezon @35g ha^{-1}, Tembotrione + Atrazine @120g+250g ha^{-1}, Topramezon + Atrazine @ 35+250g ha^{-1}, 2,4-D @500g ha^{-1}, two hand weeding, and 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. Therefore, Topramezon+Atrazine @35+250g ha^{-1} herbicide treatment was more beneficial to the farmers in maize crop.

Table 1: Various phenophases of maize under various herbicidal treatments during crop growth period

Treatments		Days to tassels Initiation	Days to Cob emergence	Days to silk appearance	Days to grain formation	Days to grain development				Days to physiologial maturity	Days to field maturity
						Days to blister stage	Days to milking stage	Days to dough stage	Days to dent stage		
T_1	Tembotrione @ 120g ha^{-1}	64.11	65.44	67.33	73.93	81.11	84.78	95.33	100.0	108.44	114.00
T_2	Topramizon @ 120g ha^{-1}	63.78	65.22	66.78	73.47	80.11	84.33	95.83	101.2	109.44	114.78
T_3	Tembotrion+Atrazine @ 120g+250g ha^{-1}	63.89	64.78	66.00	72.50	78.67	83.44	97.0	102.6	111.00	115.67
T_4	Topramizon+Atrazine @35g+250g ha^{-1}	62.56	64.44	65.00	72.07	78.00	82.56	97.67	103.5	112.11	116.56
T_5	2, 4-D @500g ha^{-1}	65.44	67.22	68.33	74.15	84.44	85.89	94.87	98.89	107.33	113.00
T_6	Hand weeding (weed free)	61.78	63.8	64.78	71.43	76.78	82.0	98.0	105.0	113.56	118.33
T_7	Control (Weedy check)	67.56	68.89	70.89	75.57	85.22	86.44	93.33	97.22	106.67	111.56
S.Em ±		0.658	0.488	0.502	0.520	0.501	0.530	0.556	0.667	0.488	0.614
CD (At 5 %)		2.02	1.506	1.54	1.604	1.543	1.635	1.713	2.056	1.503	1.892

Table 2: Yield components observed in maize crop as influenced by various herbicidal treatments

Treatments	Plant Height (Cm)	No of cobs Plant^{-1}	Cob length (cm)	Cob girth (cm)	No of grain cob^{-1}	Cob weight (g)	100 grain weight (g)
T_1	244.12	1.222	12.83	3.344	282.22	119.81	26.92
T_2	246.18	1.222	13.23	3.589	287.0	121.14	27.04
T_3	248.27	1.44	14.93	3.80	302.0	128.25	27.53
T_4	249.17	1.556	15.83	3.922	305.88	130.44	28.26
T_5	241.50	1.11	12.47	3.30	275.88	116.22	26.84
T_6	252.12	1.667	16.91	4.100	322.22	133.68	28.93
T_7	217	1.00	11.69	3.156	254.88	103.24	25.113
S.Em ±	2.4477	0.1000	0.6317	0.0812	6.8383	2.1734	0.2325
CD (at 5%)	7.5420	0.3080	1.9465	0.2501	21.0709	6.6969	0.7163

Table 3: Grain yield and Biological yield and Harvest index of maize as influenced by various herbicidal treatments

Treatments		Grain Yield		Biological Yield		Harvest index
		(g plant^{-1})	(kg ha^{-1})	(g plant^{-1})	(kg ha^{-1})	
T1	Tembotrione @ 120g ha^{-1}	20.67	2067.00	156.93	19330.27	10.74
T2	Topramizon @ 120g ha^{-1}	21.36	2136.0	158.90	19528.50	11.03
T3	Tembotrione+Atrazine @ 120g+250g ha^{-1}	23.96	2396.66	176.29	21686.00	11.08
T4	Topramizon+Atrazine @35g+250g ha^{-1}	25.17	2517.33	182.33	22442.71	11.21
T5	2, 4-D @500g ha^{-1}	18.63	1863.33	150.01	18527.64	10.06
T6	Hand weeding (weed free)	27.76	2776.33	197.42	24312.67	11.45
T7	Control (Weedy check)	12.8	1280.0	127.37	15700.83	8.15
S.Em ±		0.6716	67.160	6.7335	805.96	0.5782
CD (AT5%)		2.0694	206.941	20.748	2483.42	1.7817

Table 4: Economic analysis observed in maize crop as influenced by various herbicidal treatments

S. No.	Treatments	Total cost of cultivation (Rs.ha^{-1})	Gross monetary returns (Rs ha^{-1})	Net monetary returns (Rs.ha^{-1})	Benefit: Cost ratio
T_1	Tembotrione @ 120g ha^{-1}	26500	58450.24	31950.24	1.20
T_2	Topramizon @ 120g ha^{-1}	27050	59730.75	32680.75	1.21
T_3	Tembotrione+Atrazine @ 120g+250g ha^{-1}	26587.5	66681.4	40093.9	1.50
T_4	Topramizon+Atrazine @35g+250g ha^{-1}	27137.5	69536.35	42398.85	1.56
T_5	2, 4-D @500g ha^{-1}	25450	54343.91	28893.91	1.13
T_6	Hand weeding (weed free)	32800	76031.71	43231.71	1.32
T_7	Control (Weedy check)	25300	41790	16490	0.65

Table 5: Biochemical components of maize as influenced by various herbicidal treatments

Treatments		Protein (%)	Fat (%)	Carbohydrate (%)	Fiber (%)	Ash (%)
T1	Tembotrione @ 120g ha^{-1}	9.74	3.67	67.87	2.34	2.27
T2	Topramizon @ 120g ha^{-1}	9.79	3.65	67.61	2.37	2.36
T3	Tembotrione+Atrazine @ 120g+250g ha^{-1}	9.85	3.83	68.68	2.51	2.45
T4	Topramizon+Atrazine @35g+250g ha^{-1}	9.97	3.74	68.36	2.54	2.43
T5	2, 4-D @500g ha^{-1}	9.68	3.70	66.52	2.28	2.06
T6	Hand weeding (weed free)	9.82	3.95	69.33	2.87	2.64
T7	Control (Weedy check)	9.16	3.47	65.33	2.01	1.85
S.Em ±		0.083	0.059	0.228	0.026	0.072
CD (AT5%)		0.257	0.181	0.703	0.113	0.222

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