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RESEARCH ARTICLE

The moisture regimes and herbicides efficacy in improving productivity and profitability of spring-planted maize

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ABSTRACT

A field experiment was conducted at G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India during spring 2022 and 2023 to evaluate the impact of moisture regime and herbicide efficacy in maize (*Zea mays* L.). The experiment followed a split-plot design, with the main plots divided into two irrigation levels, *viz.* IW/CPE 0.8 and IW/CPE 1.2. Within each main plot, eight weed management treatments were tested, including atrazine 1000 g/ha, tembotrione 120 g/ha, topramezone 25.2 g/ha, atrazine 1000 g/ha *fb* hand-weeding at 35 DAS, atrazine 1000 g/ha *fb* tembotrione 120 g/ha, atrazine 1000 g/ha *fb* topramezone 25.2 g/ha, weed-free, and weedy check. Each treatment was replicated thrice in subplots. Interaction between irrigation levels and weed control practices revealed that spring maize irrigated at 1.2 IW: CPE in combinations with atrazine 1000 g/ha *fb* topramezone 25.2 g/ha produced significantly higher grain yield than other treatments. The economic analysis revealed that irrigation at 1.2 IW:CPE ratio recorded significantly higher net returns of ₹ 66207/ha and B:C (2.47). Among weed management treatments, atrazine 1000 g/ha *fb* topramezone 25.2 g/ha attained a maximum net income of ₹ 71661/ha with B:C (2.61) and next best was atrazine 1000 g/ha *fb* tembotrione 120 g/ha which fetched next highest net income (₹ 65767/ha) and B:C (2.49).

Keywords: Economics, Herbicides, Maize, Moisture regimes, Weed control efficiency

INTRODUCTION

Maize is a versatile multi-purpose crop, widely recognized as a staple food and crucial feed source globally. It occupies approximately 201.98 million hectares (mha) of land worldwide, total production of 1162.35 million tonnes (mt) and achieving an average productivity of 5.75 t/ha (ICAR-IIMR, 2021). In India, maize holds the position of the third most significant crop, following rice and wheat, covering an area of 9.89 m ha. The total production in India amounts to 35.65 mt, with an average productivity of 3.2 t/ha. As a C_4 plant, maize has high photosynthetic efficiency and can thrive in a variety of climates, including temperate, tropical, and subtropical regions (Erenstein 2022). However, there is a big gap between maize grain yield in India and the major maize-producing countries which is attributed to many challenges in maize cultivation in India; the yield gap with the USA is higher by 400% and with China, it is 225% (Mbagatuzinde 2022). The initially slow growth and wide spacing of maize plants make them susceptible to heavy weed infestations, which can significantly reduce yields. Mukhtar *et al.* (2007) highlight that unrestricted weed growth in maize fields can lead to yield reductions ranging from 67% to 79% during the summer season. Additionally, under weedy conditions, maize plants may experience an average reduction of 65% in plant height, further exacerbating yield losses. Furthermore, a concerning report on maize yield losses in India, as documented by Zaidi *et al.* (2010), indicates that approximately 25-30% of the maize crop is lost annually due to drought and waterlogging incidents. In drought conditions, herbicide application rates may need to be increased by 25-50% to achieve effective weed control compared to moist conditions (Ibrahim *et al.* 2021). These losses emphasize the urgent need for implementing climate-resilient agricultural strategies to mitigate the impact of adverse climatic conditions on maize production. Precipitation and soil moisture can directly influence herbicide uptake by washing the spray droplets off leaf surfaces or by diluting the herbicide to a less effective form (Varanasi *et al.* 2016). On the other hand, moisture stress throughout the growing season may affect both plant growth and herbicide efficacy. Maintaining optimal soil moisture levels through proper irrigation and timing herbicide applications in anticipation of precipitation events are crucial strategies for maximizing herbicide efficacy and achieving effective weed control. The IW/CPE ratio is a recognized irrigation scheduling factor that plays a crucial role in optimizing herbicide efficacy.

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By aligning irrigation practices with cumulative pan evaporation, this technique ensures that soil moisture levels are maintained at an optimal level for effective weed control, while also minimizing water loss. Thus, the objective of this research was to lower weed density while increasing spring maize output by optimizing the irrigation water regime and determining the best herbicide treatments.

MATERIALS AND METHODS

The experiment was conducted at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, during the spring seasons of 2022 and 2023. It employed a split-plot design with 16 treatment combinations, consisting of two irrigation levels and eight weed management treatments. The main plot factor involved two irrigation levels: IW/CPE:0.8 and IW/CPE 1.2 cumulative pan evaporation (CPE) intervals. In the sub-plots, the weed management treatments included: Atrazine 1000 g/ha, tembotrione 120 g/ha, topramezone 25.2g/ha, atrazine 1000 g/ha *fb* hand-weeding at 35 DAS, atrazine 1000 g/ha *fb* tembotrione 120g/ha, atrazine 1000 g/ha *fb* topramezone 25.2 g/ha, weed-free and weedy check. Each treatment combination was replicated three times. The soil characteristics were sandy loam with a pH of 7, electrical conductivity of 0.25 dS/m, organic matter content of 0.72%, available nitrogen of 281 kg/ha, available phosphorus of 25 kg/ha, and extractable potassium of 184 kg/ha. Maize hybrid Pioneer-1899 was sown on 16th February, 2022, and 28th February, 2023 with a seed rate of 20 kg/ha and spacing of 60×20 cm. The crop received fertilization with a dose of 120:26.2:33.33 N, P and K kg/ha. Daily pan evaporation and rainfall data were collected from the meteorological observatory located at the research farm of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, to calculate the Cumulative Pan Evaporation (CPE) values. During the maize growing seasons of 2022 and 2023, cumulative rainfall amounts of 74.5 mm and 225.6 mm, respectively, were observed, alongside corresponding pan evaporation values of 486.4 mm and 668.4 mm. The total number of irrigation events recorded under an IW/CPE ratio of 0.8 was 3 in 2022 and 4 in 2023, whereas under an IW/CPE ratio of 1.2, the respective irrigation frequencies were 7 and 5. Weed density was assessed at 60 DAS using a quadrat of 50 x 50 cm (0.25m^2) size positioned at the center of each plot. Weeds within the quadrat were uprooted, cut close to the root-shoot transition, and subsequently shade-dried for 2-3 days before being further dried in a hot air oven at 65±5°C until a constant weight was achieved, to determine dry matter accumulation (biomass). The dried samples were weighed and expressed as biomass (g/m^2). Data on weeds, including weed density and dry weight, were normalized using square root transformation with an additional factor of 0.5. Weed control efficiency (WCE) was calculated using formulae as suggested by Mani *et al.* (1973). Growth, yield, and economic data were statistically analysed using standard procedures.

RESULTS AND DISCUSSION

Weed flora

Among the weeds, grasses and sedges weeds were dominant in the experimental site as compared to the broad-leaved weeds (**Table 1**). *Cyperus rotundus* L. was the dominant weed followed by *Digitaria sanguinalis L.*, *Alternanthera sessilis* L., *Sorghum halepense* and *Eleusine indica* L., during both years of study.

Effect on weeds

At 60 DAS, the total weed density and weed biomass were found lower at IW/CPE 1.2 CPE in comparison to IW/CPE 0.8 (**Table 1** and **2**). Adequate soil moisture in the IW/CPE 1.2 facilitates the movement of pre-emergence herbicides into the zone of weed seed germination, thereby contributing to effective weed control. Additionally, the improved herbicide absorption, translocation, and metabolism of post-emergence herbicides in the IW/CPE 1.2 compared to the lower moisture conditions of IW/CPE 0.8. This reduction in adsorption of herbicides at IW/CPE 1.2 to soil particles enhances the availability of herbicides for uptake by plant roots, ultimately leading to improved weed control efficacy (Varanasi *et al.* 2016). Moreover, the dense canopy of maize plants under IW/CPE 1.2 inhibits weed seed germination and reduced growth rate of established weeds by limiting the amount of light reaching the soil surface germination and reduced growth rate of established weeds by limiting the amount of light reaching the soil surface.

Among weed management treatments, atrazine 1000 g/ha *fb* topramezone 25.2 g/ha followed by atrazine 1000 g/ha *fb* tembotrione 120g/ha recorded the lowest weed density at 60 DAS (**Table 1**). The density of *Digitaria sanguinalis* was reduced by 89.6%, *Sorghum halepense* by 76.4%, *Eleusine indica* by 78.3%, *Cyperus rotundus* by 63.3% and *Alternanthera sessilis* by 87% compare to the weedy check plot. Similarly at 60 DAS, total weed biomass significantly recorded lowest at atrazine 1000 g/ha *fb* topramezone 25.2g/ha followed by atrazine 1000g/ha *fb* tembotrione 120 g/ha (**Table 2**). The total weed biomass was lower by 53.5% and 76.1% as compared to atrazine 1000 g/ha applied alone and weedy check plot (**Table 2**). Sequential mixtures of atrazine and topramezone provide complementary and synergistic weed control effects. Atrazine primarily targets grass and certain broadleaf weeds, while topramezone offers additional control of broad-leaf weeds, including those tolerant to atrazine. Under herbicidal treatments, the weed control efficiency at 60 DAS was significantly higher in atrazine 1000 g/ha *fb* topramezone 25.2 g/ha (77.2%) which was statistically at par to atrazine 1000 g/ha *fb* tembotrione 120 g/ha (76.9%) owing to reduce weed biomass (**Table 4**). This sequential application of herbicides ensures comprehensive weed suppression throughout the crop growth period, ultimately leading to higher weed control efficiency at 60 DAS. These results are in accordance with Kakde *et al.* (2020), Rani *et al.* (2022) and Reddy *et al.* (2022).

Effect on crop

Data from two years indicated a significant variation in growth attributes, yield attributes, and yield across different moisture regimes. Irrigation at IW/CPE 1.2 had a notable impact, with pooled plant height reaching 246.9 cm. The number of grain rows per cob was 15.8 in 2022 and 15.9 in 2023, while the number of grains per row was recorded at 33.2 in 2022 and 33.5 in 2023. Grain yield was 6.0 t/ha in 2022 and 6.1 t/ha in 2023 (**Table 4**). The frequent irrigations under IW/CPE 1.2 ensured sufficient soil moisture availability throughout the growing season. This promotes the expansion of leaf surface area, maximizes photosynthetic efficiency, and increases the production of carbohydrates, ultimately leading to larger, more developed ears with well-filled kernels. Furthermore, the vigorous growth of maize extensive root system and release of allelochemicals; benzoxazines, phenolics, flavonoids, and terpenoids outcompeted the weeds for essential resources

Table 1. Effect of moisture regime and weed management on weed density at 60 days after sowing in spring planted maize (pooled mean)

Treatment	*Digitaria sanguinalis*	*Sorghum halepense*	*Eleusine indica*	*Cyperus rotundus*	*Alternanthera sessilis*	Total weed Density
Moisture regime						
IW/CPE 0.8	5.4(37.2)	4(17.9)	3.6(13.9)	8.9(91.1)	3.8(16.8)	12.6(189.6)
IW/CPE 1.2	5.2(35)	3.9(17)	3.5(13.2)	9(91.6)	3.8(16.1)	12.4(185.4)
LSD(p=0.05)	NS	NS	NS	NS	NS	NS
Weed management						
Atrazine 1000 g/ha	8.1(65.5)	5.5(29.7)	4.5(19.4)	10.2(102.9)	5.1(25.1)	16.2(261.1)
Tembotrione 120 g/ha	4.9(23.4)	4.2(17)	3.5(11.3)	9.6(90.3)	4(15)	13(167.7)
Topramezone 25.2 g/ha	4.8(22.1)	4.2(17)	3.4(10.5)	9.5(89.4)	3.8(13.9)	12.8(162.5)
Atrazine 1000 g/ha *fb* hand-weeding (35 DAS)	5(23.8)	3.4(10.8)	3.2(9.6)	9.8(94.3)	3.3(9.9)	12.5(156.5)
Atrazine 1000 g/ha *fb* tembotrione 120 g/ha	3.8(13.8)	3.5(11.1)	3.1(8.8)	8.7(74.8)	3(8.1)	11.2(124.8)
Atrazine 1000 g/ha *fb* topramezone 25.2 g/ha	3.7(13.2)	3.3(10.3)	3.1(8.7)	8.7(74.4)	2.8(6.9)	11.1(121.4)
Weed free	1(0)	1(0)	1(0)	1(0)	1(0)	1(0)
Weedy check	11.3(127.1)	6.7(43.6)	6.4(40.1)	14.3(204.6)	7.3(53)	22.5(506)
LSD(p=0.05)	0.22	0.20	0.18	0.22	0.20	0.25

Data were square root transformed and values in parentheses are actual mean values

Table 2. Effect of moisture regime and weed management on weed biomass at 60 days after sowing in spring planted maize (pooled mean)

Treatment	*Digitaria sanguinalis*	*Sorghum halepense*	*Eleusine indica*	*Cyperus rotundus*	*Alternanthera sessilis*	Total weed biomass
Moisture regime						
IW/CPE 0.8	6.5(50.9)	4.4(21.7)	3.2(10.6)	6(41.3)	6.4(46.4)	12.4(185.9)
IW/CPE 1.2	6.4(48.5)	4.3(20.9)	3(9.7)	6(41)	6.4(46.6)	12.2(178.9)
LSD(p=0.05)	NS	NS	NS	NS	NS	NS
Weed management						
Atrazine 1000 g/ha	9.2(84.1)	6.2(37.1)	3.9(14.3)	8.3(68.9)	8.6(73)	17.2(296.3)
Tembotrione 120 g/ha	6.5(40.7)	4.6(20.2)	3.1(8.4)	5.8(33)	6.7(43.5)	12.7(160.9)
Topramezone 25.2 g/ha	6.3(39.5)	4.6(19.9)	3(8.2)	5.8(32.9)	6.6(42.3)	12.6(158.2)
Atrazine 1000 g/ha *fb* hand-weeding (35 DAS)	6.4(40.6)	4.5(19.1)	2.6(5.7)	5.7(32)	6.1(36.6)	11.9(140.9)
Atrazine 1000 g/ha *fb* tembotrione 120 g/ha	5(23.7)	3.7(12.7)	2.7(6.3)	5.2(26.3)	6(35.3)	10.6(111.3)
Atrazine 1000 g/ha *fb* topramezone 25.2 g/ha	4.8(22)	3.6(12.1)	2.7(6.2)	5.2(25.6)	5.9(34.3)	10.4(107.2)
Weed free	1(0)	1(0)	1(0)	1(0)	1(0)	1(0)
Weedy check	12.1(146.8)	7.1(49.6)	5.7(31.2)	10.5(110.3)	10.4(106.8)	22(484.8)
LSD(p=0.05)	0.21	0.22	0.19	0.18	0.31	0.32

Data were square root transformed and values in parentheses are actual mean values

(Jabran 2017). According to Bednarz *et al.* (2023), soil microflora can convert allelochemicals such as phenolic compounds and benzoxazines into more potent bioherbicides. Because of their phytotoxicity, specific activity, and short soil persistence, these allelochemicals may be effective weed control agents.

Weed management treatments had a significant influence on growth, yield-attributing traits, and grain yield. The weed-free plot recorded the highest values, with pooled plant height reaching 250.7 cm. The number of grain rows per cob was 17.0 in 2022 and 17.1 in 2023, while the number of grains per row was 34.7 in 2022 and 35.3 in 2023. Grain yield was 6.9 t/ha in 2022 and 7.0 t/ha in 2023 (**Table 4**). These values were statistically comparable to treatments with atrazine at 1000 g/ha followed by topramezone at 25.2 g/ha and atrazine at 1000 g/ha followed by tembotrione at 120 g/ha. The growth attributes, yield attributes and grain yield in the weedy check were significantly low in both years. In the initial stage of crop growth, atrazine prevents weed seeds from germinating or disrupts early seedling growth, effectively reducing weed populations in the field, while post-emergence herbicides; topramezone and tembotrione controlled all weed species including those that may have survived atrazine, as it depletes carotenoids and stops chloroplast development causing bleaching and necrosis of foliar tissue (Fluttert *et al.* 2022). This reduces the crop's competition with weeds, enhancing the crop's vegetative and reproductive potential, and physically preventing weeds from emerging and growing by depriving them of access to nutrients, moisture, light, and space. The present findings were in accordance with the earlier findings of Rani *et al.* (2022) and Sivamurugan *et al.* (2024).

Interaction

Critical assessment of data revealed that the interaction effect (I × W) between irrigation intervals and weed management on grain yield was found to be significant (**Table 3**).The grain yield recorded significantly higher in combination of atrazine 1000 g/ha *fb* topramezone 25.2g/ha (6.91 t/ha) with irrigation scheduling at IW/CPE 1.2 over all other treatment combinations, which was statistically at par with atrazine 1000 g/ha *fb* tembotrione 120 g/ha (6.33 t/ha) under similar moisture regime. However, treatment combination at IW/CPE 0.8 intervals; atrazine 1000 g/ha *fb* tembotrione 120 g/ha (5.75 t/ha) coupled with IW/CPE 0.8 and atrazine 1000 g/ha *fb* topramezone 25.2 g/ha (5.74 t/ha) with IW/CPE 0.8 being at par with each other and found to be significantly higher over rest of treatment combinations.

Economics

The net monetary returns (₹ 66207/ha) and B:C ratio (2.47) in maize were significantly higher with irrigation at IW/CPE 1.2 (**Table 4**). Optimal soil moisture conditions at IW/CPE 1.2 promote vigorous growth and development of maize plants, resulting in better crop performance and higher grain yields outweigh the additional cost of frequent irrigation.

Among weed management treatments, the highest net return (₹ 71661/ha) and B:C ratio (2.61) was obtained with atrazine 1000 g/ha *fb* topramezone 25.2 g/ha closely followed by weed-free and atrazine 1000 g/ha *fb* tembotrione 120 g/ha (**Table 4**). The lowest net return (₹ 33271/ha) and B:C ratio (1.91) was in weedy check due to heavy weed infestation and yield decline. These results were in conformity with the results obtained by Rani *et al.* (2022), Reddy *et al.* (2022) and Kaul *et al.* (2023).

The two-year study demonstrated that for effective weed control, to achieve higher maize productivity and maximize net monetary returns, a pre-emergence (PE) application of atrazine at 1000 g/ha followed by (*fb*) post-emergence (PoE) application of topramezone at 25.2 g/ha, coupled with

Table 3. Interaction effect of moisture regime and weed management treatments (I × W) on maize grain yield (pooled data of two year)

Treatment (I × W)	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	Moisture regime means
I_1	4.51	5.11	5.52	5.64	5.75	5.74	6.67	3.23	5.27
I_2	5.38	6.08	6.11	6.29	6.33	6.91	7.17	4.04	6.04
Weed management mean	4.94	5.60	5.81	5.97	6.04	6.32	6.91	3.63	
								SEm±	LSD(p=0.05)
Two weed management at the same irrigation interval								0.13	0.40
Two moisture regimes at the same or different weed management								0.17	0.41
Irrigation interval (I)								0.05	0.17
Weed management (W)								0.12	0.35

I_1: IW/CPE 0.8, I_2: IW/CPE 1.2, W_1: atrazine 1000 g/ha, W_2: tembotrione 120 g/ha, W_3: topramezone 25.2g/ha, W_4: atrazine 1000 g/ha *fb* hand-weeding (35 DAS), W_5: atrazine 1000g/ha *fb* tembotrione 120 g/ha, W_6: atrazine 1000g/ha *fb* topramezone 25.2 g/ha, W_7: weed free, W_8: weedy check

Table 4. Effect of moisture regime and weed management on growth, yield and economics in spring planted maize (pooled mean)

Treatment	Plant height (cm)	2022 No. of grain rows / cob	2022 No. of grains /row	2022 Grain yield (t/ha)	2023 No. of grain rows /cob	2023 No. of grains /row	2023 Grain yield (t/ha)	Weed control efficiency (%)	Net returns (₹/ha)	B:C ratio
Moisture regime										
IW/CPE 0.8	222.1	13.9	29.1	5.2	14.0	29.4	5.4	61.6	497780	2.15
IW/CPE 1.2	246.9	15.8	33.2	6.0	15.9	33.5	6.1	64.3	66207	2.47
LSD(p=0.05)	9.3	1.9	3.5	0.5	1.6	3.3	0.6	NS	-	-
Weed management										
Atrazine 1000 g/ha	220.6	14.0	29.6	4.8	14.1	29.7	5.1	39.4	48414	2.24
Tembotrione 120 g/ha	231.1	14.2	30.9	5.7	14.3	31.5	5.6	67.7	56032	2.32
Topramezone 25.2 g/ha	232.1	14.4	31.3	5.9	14.4	31.6	5.9	69.2	58393	2.38
Atrazine 1000 g/ha *fb* hand-weeding (35 DAS)	242.2	14.6	31.8	6.0	14.6	32.0	6.1	71.5	64177	2.44
Atrazine 1000 g/ha *fb* tembotrione 120 g/ha	244.7	15.0	32.0	6.0	15.1	32.1	6.1	77.5	65767	2.49
Atrazine 1000 g/ha *fb* topramezone 25.2 g/ha	245.9	15.8	32.2	6.1	15.9	32.5	6.6	78.2	71661	2.61
Weed free	250.7	17.0	34.7	6.9	17.1	35.3	7.0	100	66234	2.08
Weedy check	208.7	14.0	26.7	3.5	14.2	26.9	3.9	0.00	33271	1.91
LSD(p=0.05)	11.7	1.6	2.9	0.5	1.6	3.3	0.6	3.6	-	-

irrigation scheduling at IW/CPE 1.2, proved to be the most effective strategy. By integrating optimized weed management and irrigation practices under evolving climate patterns, farmers can mitigate weed pressures, optimize crop productivity and enhance maize resilience to changing environmental conditions, while ensuring sustainable yields and economic viability in the *Tarai* region of Uttarakhand.

REFERENCES

Bednarz MK, P³onka J and Barchanska H. 2023. Allelopathy as a source of bioherbicides: Challenges and prospects for sustainable agriculture. *Reviews in Environmental Science and Biotechnology* **22**(2): 471–504.

Erenstein O, Jaleta M, Sonder K, Mottaleb K and Prasanna BM. 2022. Global maize production, consumption and trade: Trends and R&D implications. *Food security* **14**(5): 1295–1319.

Fluttert JC, Soltani N, Galla M, Hooker DC, Robinson DE and Sikkema PH. 2022. Additive and synergistic interactions of 4-hydroxyphenylpyruvate dioxygenase (HPPD) and photosystem II (PSII) inhibitors for the control of glyphosate-resistant horseweed (*Conyza canadensis*) in corn. *Weed Science* **70** (3): 319–327.

ICAR-IIMR. 2021.*Annual Report 2020-2021*. ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi-110012.

Ibrahim HH, Abdalla AA and Salem WS. 2022. Efficacy of irrigation intervals and chemical weed control on optimizing bulb yield and quality of onion (*Allium cepa* L.). *Bragantia* **81**: e1722.

Jabran K. 2017. Maize allelopathy for weed control. In: *Manipulation of Allelopathic Crops for Weed Control*. Springer Briefs in Plant Science. Springer, Cham. https://doi.org/10.1007/978-3-319-53186-1

Kakade SU, Deshmukh JP, Thakare SS and Solanke MS. 2020. Efficacy of pre-and post-emergence herbicides in maize. *Indian Journal of Weed Science* **52**(2): 143–146.

Kaul A, Singh B and Singh M. 2023. Weed management with pre-and post-emergence herbicides in *Kharif* maize in sub-mountainous area of Punjab, India. *Indian Journal of Weed Science* **55**(1): 32–35.

Mani V, Pandita M, Gautam KC and Bhagwandas. 1973. Weed killing chemicals in potato cultivation. *Indian Farming* **23**: 7–13.

Mbagatuzinde K, Bhullar MS, Kaur T and Brar AS. 2022. Weed management in maize through integration of drip irrigation, mulch and herbicide. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* **92**(4): 791–800.

Mukhtar AM, Eltahir SA, Siraj OM and Hamada AA. 2007. Effect of weeds on growth and yield of maize (*Zea mays* L.) in Northern State, Sudan. *Sudan Journal of Agricultural Research* **8**: 1–7.

Rani BS, Chandrika V, Reddy GP, Sudhakar P, Nagamadhuri KV and Sagar GK. 2022. Weed dynamics and nutrient uptake of maize as influenced by different weed management practices. *Indian Journal of Agricultural Research* **56**(3): 283-289.

Reddy MB, Elankavi S, Baradhan G and Muthuselvam K. 2022. Evaluation of weed management practices on weed dynamics and yield of maize (*Zea mays* L.). *Crop Research* **57**(5&6): 330–334.

Sivamurugan A, Pazhanivelan S, Suganthi A, Bharathi C, Raju M, Manivannan V and Kumaresan P. 2024. Efficacy of new generation herbicide mixtures in irrigated maize (*Zea mays*). *The Indian Journal of Agricultural Sciences* **94**(11): 1183–1188.

Varanasi A, Prasad, PVV and Jugulam M. 2016. Impact of Climate Change Factors on Weeds and Herbicide Efficacy. *Advances in Agronomy* **135**: 107–146.

Zaidi P, Yadav M, Maniselvan P, Khan R, Shadakshari T, Singh R and Pal D. 2010. Morpho-physiological traits associated with cold stress tolerance in tropical maize (*Zea mays* L.). *Maydica* **55**: 201–208.