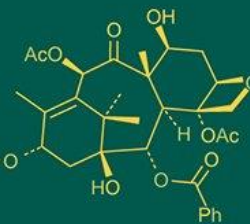
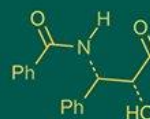
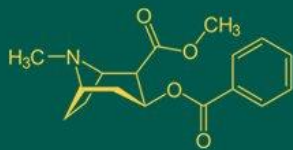


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Phytotoxicity assessment of pre and post emergent herbicides in direct seeded finger millet (*Eleusine coracana* L.)

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Abstract

Finger millet is an important nutri-cereal crop cultivated in many parts of the world and is a staple food crop in India, especially in Southern India. Although there is high demand for the crop because of its nutritional value, drought hardy nature, less input requirement, the low productivity is a major concern due to severe weed competition in direct seeded finger millet. Hence, the present investigation was formulated with the objective of screening pre and post emergent herbicides to know their phytotoxicity effect on direct seeded finger millet as a ray of hope for effective weed management. Two experiments were designed and conducted during *kharif* 2020 at College of Agriculture, VC Farm, Mandya. The experiments were laid out in randomized complete block design with three replications consisting of 11 treatments each. The treatments consisted of five pre-emergence herbicides (Atrazine, oxadiargyl, bensulfuron methyl + pretilachlor, pendimethalin and pretilachlor) and five post-emergence herbicides (Cyhalofop-butyl, Bispyribac sodium, ethoxysulfuron, Metsulfuron methyl + Chlorimuron ethyl, and 2,4-D Na salt), along with one control at two doses each in the 1st and 2nd experiment, respectively. The observations on phytotoxicity ratings along with the effect of herbicides on growth attributes such as plant height and dry matter accumulation on direct seeded finger millet were noticed up to 45 days after sowing. The results of the experiments indicated that, among the pre-emergence herbicides tested, pendimethalin and bensulfuron methyl + pretilachlor when used at 500 g a.i. ha⁻¹ and at 165 g a.i. ha⁻¹, respectively did not show phytotoxic effect and among the post-emergence herbicides, Metsulfuron methyl + Chlorimuron ethyl 20 WP (2+2) and 2,4-D Na salt 80 WP when used at 20 g a.i. ha⁻¹ and at 1000 g a.i. ha⁻¹ have no phytotoxic effect implying the possibility of using these herbicides as an effective weed management option in direct seeded finger millet.

Keywords: Finger millet, weed management, herbicides

Introduction

Finger millet, popularly known as ragi, is one among the nutri-cereals and staple cereal food crop for majority of people in the arid and semi-arid tropics of South Asia and Africa. It is the fourth most important millet in the world, next to sorghum, pearl millet, and foxtail millet (Kankarwal *et al.*, 2024) [11]. In India, the area under the cultivation occupies an area of 12.14 million hectares, with a production of 16.69 million tonnes and productivity of 1375 kg ha⁻¹ (Anon., 2024) [2]. Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Bihar, Jharkhand, Gujarat, Maharashtra and parts of Uttar Pradesh and Himachal Pradesh are major finger millet growing states. In Karnataka, cultivation of finger millet accounts to 8.27 lakh hectares with production of 10.34 lakh tonnes and productivity of 1251 kg ha⁻¹ (Anon., 2024) [2]. At global level increasing health concerns, such as diabetes, obesity, heart problems, malnutrition and so on, have led to enhanced demand for nutritious food comprising complex carbohydrates, higher dietary fibre and phytochemicals (Srivastava and Arya, 2021; Mazumder *et al.*, 2025) [13]. However, there is sharp decline in productivity level of finger millet which could be attributed to constraints such as imbalanced nutrition, untimely weed management, increasing labour wages, incidence of blast disease *etc* (Odeph, 2023) [14]. Early weed management is crucial for achieving higher yields which otherwise would result in drastic reduction in yield even up to 34 to 61% (Giri *et al.*, 2024) [7]. Although conventional

weed management methods are successful in managing the weeds, they are associated with huge labour dependency. Therefore, need for chemical weed management, especially in direct seeded situations, is an essential criterion to address the problem of labour scarcity without affecting the yield levels of finger millet. Hence, this present investigation was articulated for identifying suitable herbicides either as pre-emergence or post emergence application and to know its effect on direct finger millet.

Material and methods

Two field experiments were conducted at College of Agriculture, VC Farm, Mandya during *Kharif* 2020, laid out in randomized complete block design consisting of eleven treatments each, replicated thrice. Composite soil samples were collected and subjected to analysis. The soil of the experimental site has a textural class of red sandy loam with neutral pH (7.2). The soil was low in available nitrogen (243.2 kg ha⁻¹), low in phosphorus (19.21 kg ha⁻¹) and medium in available potassium (224.28 kg ha⁻¹). The first and second experiments consisted of five different pre-emergence and post emergence herbicides at two doses each. The treatments of the first experiment included T₁: Oxidiazinyl 80 WP @ 50 g a.i. ha⁻¹, T₂: Oxidiazinyl 80 WP @ 75 g a.i. ha⁻¹, T₃: Atrazine 50 WP @ 500 g a.i. ha⁻¹, T₄: Atrazine 50 WP @ 750 g a.i. ha⁻¹, T₅: Bensulfuron methyl + Pretilachlor 6.6% G @ 165 g a.i. ha⁻¹, T₆: Bensulfuron methyl + Pretilachlor 6.6% G @ 330 g a.i. ha⁻¹, T₇: Pendimethalin 30 EC @ 500 g a.i. ha⁻¹, T₈: Pendimethalin 30 EC @ 1000 g a.i. ha⁻¹, T₉: Pretilachlor 50 EC @ 500 g a.i. ha⁻¹, T₁₀: Pretilachlor 50 EC @ 750 g a.i. ha⁻¹ and T₁₁: Control. Second experiment consisted of treatments T₁: Cyhalofop-butyl 10 EC @ 50 g a.i. ha⁻¹, T₂: Cyhalofop-butyl 10 EC @ 75 g a.i. ha⁻¹, T₃: Bispyribac sodium 10 EC @ 15 g a.i. ha⁻¹, T₄: Bispyribac sodium 10 EC @ 20 g a.i. ha⁻¹, T₅: Ethoxysulfuron 15 WG @ 12 g a.i. ha⁻¹, T₆: Ethoxysulfuron 15 WG @ 15 g a.i. ha⁻¹, T₇: Metsulfuron methyl + Chlorimuronethyl 20 WP (2+2) @ 10 g a.i. ha⁻¹, T₈: Metsulfuron methyl + Chlorimuronethyl 20 WP (2+2) @ 20 g a.i. ha⁻¹, T₉: 2,4-D Na salt 80 WP @ 750 g a.i. ha⁻¹, T₁₀: 2,4-D Na salt 80 WP @ 1000 g a.i. ha⁻¹ and T₁₁: Control. Short duration finger millet variety KMR 630 was used in these experiments at the rate of 12.5 kg ha⁻¹ seed rate. The crop was sown with KMR 630 finger millet variety at a spacing of 30 cm apart rows and later thinning was done to maintain an intra row spacing of 10 cm. The pre-emergence herbicides were applied on third day after sowing with spray volume of 750 l ha⁻¹ and post-emergence herbicides were sprayed after 20 days after sowing with spray volume of 500 l ha⁻¹ as per the treatments. Visual crop phytotoxicity observations were recorded at 0, 1, 3, 5, 7, 10, 15, 18, 20 and 25 days after herbicide application in the scale of 0 to 10 (Rao, 1986) for both the experiments. The observations on germination percentage, plant height and dry matter accumulation (at 15, 30 and 45 DAS) were also recorded up to 45 days after sowing. The data was subjected to statistical analysis as described by Gomez and Gomez (1984) [9] by using F test.

Results and Discussion

Experiment I

Phytotoxicity of Different Pre- Emergence Used at Varied Doses on Finger Millet

The observations made on phytotoxicity of pre-emergence herbicides are presented in table 2. The phytotoxicity scoring of 7-8 was observed with Atrazine 50 WP @ 500 and 750 g a.i. ha⁻¹ indicating severe injury, stand loss and survival of few plants. Application of Oxidiazinyl 80 WP @ 50 and 75 g a. i. ha⁻¹ recorded 4-5 with initial toxicity to finger millet crop but eventually recovered. Plots receiving Pretilachlor 50 EC @ 500 and 750 g a. i. ha⁻¹ also showed toxicity with a rating of 9 and loss of plant population. Atrazine causes decline in photosynthesis because of reduction in photosystem-II which could be the reason for observation of phytotoxicity in finger millet. Similar observation with Atrazine is also reported by Bai *et al.* (2015) [3]. Higher doses of atrazine in foxtail millet, reduced photosynthetic content of the leaves (Guo *et al.*, 2005 and Su *et al.*, 2016) [10, 19]. Oxadiargyl inhibits protoporphyrinogen oxidase leading to rapid membrane peroxidation and cellular death. Oxidiazinyl at higher doses in rice showed similar toxicity (Lee and Duke, 1994 and Dickmann *et al.*, 1997) [12, 6]. Selective mechanisms of Pretilachlor might make young finger millet seedlings relatively sensitive to its application. These results are in concurrence with Ie Sung *et al.* (1990) [21]. Among the various herbicides tested, Bensulfuron methyl + Pretilachlor 6.6% G @ 165 g a.i. ha⁻¹ and Pendimethalin 30 EC @ 500 g a.i. ha⁻¹, did not exhibit any crop phytotoxicity up to 40 DAS. The results are in conformity with Yathisha *et al.* (2020) [20].

Germination Percentage of Finger Millet as Influenced by Pre-Emergence Herbicides:

The application of pre-emergence herbicides markedly reduced finger millet germination compared to the control (87%). Treatments with Oxidiazinyl (50 and 75 g a.i. ha⁻¹), Atrazine (500 and 750 g a.i. ha⁻¹), Pendimethalin (1000 g a.i. ha⁻¹) and Pretilachlor (500 and 750 g a.i. ha⁻¹) resulted in germination ranging from 55% to 68%, indicating a substantial decline. These findings align with earlier reports where higher doses of Oxidiazinyl, Atrazine, Pendimethalin and Pretilachlor suppressed germination and early seedling growth in various crops (Nethra and Jagannath; Gitsopoulos and Froud-Williams, 2004; Ahmed and Chauhan, 2015; Dan *et al.*, 2010; Burhan and Shaukat, 2000; Singh *et al.*, 2004) [8, 1, 5, 4, 17]. On the contrary, Bensulfuron methyl + Pretilachlor 6.6% G (165 g a.i. ha⁻¹) and Pendimethalin at the lower dose (500 g a.i. ha⁻¹) had minimal impact on germination, supporting the observations of Yathisha *et al.* (2020) [20].

Plant Height of Finger Millet as Influenced by Pre-Emergence Herbicides:

The height of the direct-seeded finger millet was significantly affected by pre-emergence herbicide application at 15, 30 and 45 DAS (Fig.1). The taller plants steadily occurred in the control plots, (15.83, 24.08 and 40.58 cm, respectively at different stages) indicating the absence of herbicidal stress. Plant height under pendimethalin @ 500 g a.i. ha⁻¹ (14.73, 23.73 and 40.12 cm, at 15, 30 and 45 DAS, respectively) was statistically on par with the control. This was followed by bensulfuron methyl + pretilachlor @ 165 g a.i. ha⁻¹ application (13.17, 21.17 and 37.69 cm at 15, 30 and 45 DAS, respectively). All other herbicide treatments resulted

in a significant reduction in plant height, which might be due to phytotoxic effects.

Dry Matter Accumulation of Finger Millet as Influenced by Pre-Emergence Herbicides: The dry matter accumulation of direct-seeded finger millet was significantly influenced by pre-emergence herbicide application at 15, 30 and 45 DAS (Fig.2). Control plots consistently recorded the higher dry matter accumulation (5.63, 12.13 and 24.33 g per 0.5 m row length at 15, 30 and 45 DAS, respectively). These were statistically on par with pendimethalin @ 500 g a.i. ha⁻¹ (5.38, 11.37 and 25.75 g per 0.5 m row length at 15, 30 and 45 DAS, respectively) and were followed by bensulfuron methyl +pretilachlor @ 165 g a.i. ha⁻¹ (5.30, 9.23 and 24.65 g g per 0.5 m row length at 15, 30 and 45 DAS, respectively). All other herbicides resulted in significantly lower dry matter accumulation, which might be a consequence of phytotoxic effect.

Experiment: II

Phytotoxicity of Different Post Emergence Herbicides Used at Varied Doses on Finger Millet

The visual phytotoxicity ratings of post-emergence herbicides in finger millet recorded are presented in the table 3. Cyhalofop-butyl 10 EC @ 50 and 75 g a.i. ha⁻¹ (4-8 ratings) caused severe discoloration and plant mortality. The results are consistent with earlier findings reporting up to 44% plant death at 21 days after application (Pandey *et al.*, 2018)^[15]. Bispyribac sodium 10 EC @ 15 and 20 g a.i. ha⁻¹ also induced noticeable phytotoxicity (5-7), including stand reduction, stunted growth and discoloration, which are in concurrence with observations by Yathisha *et al.* (2020)^[20]. Although, Ethoxysulfuron 15 WG @ 12 and 15 g a.i. ha⁻¹ caused no visible injury, it was ineffective in weed control

and was therefore excluded from further studies. In contrast, Metsulfuron methyl +Chlorimuron ethyl 20 WP (2+2) @ 10 and 20 g a.i. ha⁻¹ and 2,4-D Na salt 80 WP @ 1000 g a.i. ha⁻¹ produced minimal or no phytotoxic effects on finger millet, aligning with previous reports (Pandey *et al.*, 2018)^[15].

Plant Height of Finger Millet as Influenced by Post-Emergence Herbicides:

The plant height of finger millet as influenced by different post-emergence herbicide treatments (Fig. 3) showed significant variation. All herbicides, except Metsulfuron methyl +Chlorimuron ethyl 20 WP (2+2) @ 10 (10.72, 22.06 and 38.31 cm at 15, 30 and 45 DAS, respectively) and 20 g a.i. ha⁻¹ (10.36, 21.73 and 37.84 cm at 15, 30 and 45 DAS, respectively) and 2,4-D Na salt 80 WP @ 750 (10.46, 21.57 and 37.22, at 15, 30 and 45 DAS, respectively) and 1000 g a.i. ha⁻¹ (10.81, 20.38 and 37.34 cm at 15, 30 and 45 DAS, respectively) caused significant reduction in plant height at 15, 30 and 45 DAS. The reduction could be attributed to phytotoxic effect leading to suppressed growth.

Dry Matter Accumulation of Finger Millet as Influenced by Post-Emergence Herbicides

Dry matter accumulation was also significantly influenced by post-emergence herbicide application (Fig. 4). The highest dry matter values were recorded with Metsulfuron methyl +Chlorimuron ethyl 20 WP (2+2) @ 10 and 20 g a.i. ha⁻¹ and 2,4-D Na salt 80 WP @ 750 and 1000 g a.i. ha⁻¹, which might be due to the absence of phytotoxicity, allowing normal crop growth. In contrast, Cyhalofop-butyl resulted in the lowest dry matter accumulation, consistent with earlier reports of its phytotoxic effects (Pandey *et al.*, 2018)^[15] on finger millet.

Table 1: The Crop phytotoxicity ratings on a scale of 0 to 10 (Rao, 1986)

Effect	Rating	Weed	Crop
None	0	No control	No injury, normal
Slight	1	Very poor control	Slight stunting, injury or discolouration
	2	Poor control	Some stand loss, stunting or discolouration
	3	Poor to deficient control	Injury more pronounced but not persistent
Moderate	4	Deficient control	Moderate injury, recovery possible
	5	Deficient to moderate control	Injury more persistent, recovery doubtful
	6	Moderate control	Near severe injury no recovery possible
Severe	7	Satisfactory control	Severe injury stand loss
	8	Good control	Almost destroyed a few plants surviving
	9	Good to excellent control	Very few plants alive
Complete	10	Complete control	Complete destruction

Table 2: Visual Phytotoxicity ratings in the scale of 0 to 10 for direct seeded finger millet crop as influenced by pre-emergence herbicides

Pre-emergent herbicides	Crop phytotoxicity ratings (DAHS)									
	0	1	3	5	7	10	15	18	20	25
T1: Oxidargyl 80 WP @ 50 g a.i. ha ⁻¹	4	4	4	4	4	4	4	4	0	0
T2: Oxidargyl 80 WP @ 75 g a.i. ha ⁻¹	5	5	5	5	5	5	5	5	5	5
T3: Atrazine 50 WP @ 500 g a.i. ha ⁻¹	7	7	7	7	7	7	7	7	7	7
T4: Atrazine 50 WP @ 750 g a.i. ha ⁻¹	8	8	8	8	8	8	8	8	8	8
T5: Bensulfuron methyl + Pretilachlor 6.6% G @ 165 g a.i. ha ⁻¹	0	0	0	0	0	0	0	0	0	0
T6: Bensulfuron methyl + Pretilachlor 6.6% G @ 330 g a.i. ha ⁻¹	1	1	2	2	2	3	3	3	3	3
T7: Pendimethalin 30 EC @ 500 g a.i. ha ⁻¹	0	0	0	0	0	0	0	0	0	0
T8: Pendimethalin 30 EC @ 1000 g a.i. ha ⁻¹	4	4	5	5	5	6	6	6	6	6
T9: Pretilachlor 50 EC @ 500 g a.i. ha ⁻¹	8	8	8	8	8	8	8	8	8	8
T10: Pretilachlor 50 EC @ 750 g a.i. ha ⁻¹	9	9	9	9	9	9	9	9	9	9
T11: Control	0	0	0	0	0	0	0	0	0	0

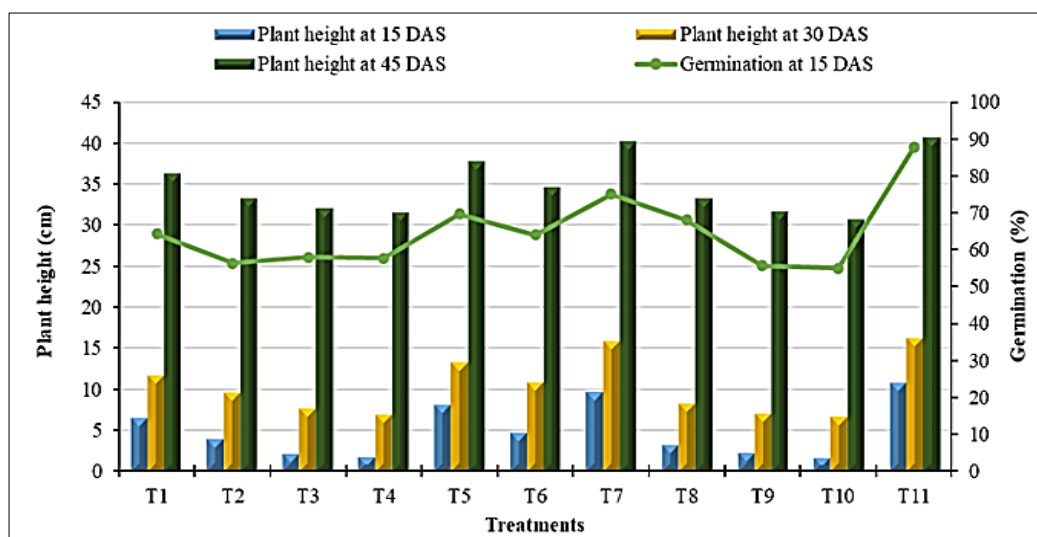


Fig 1: Germination percentage and plant height of direct seeded finger millet as influenced by pre-emergence herbicides

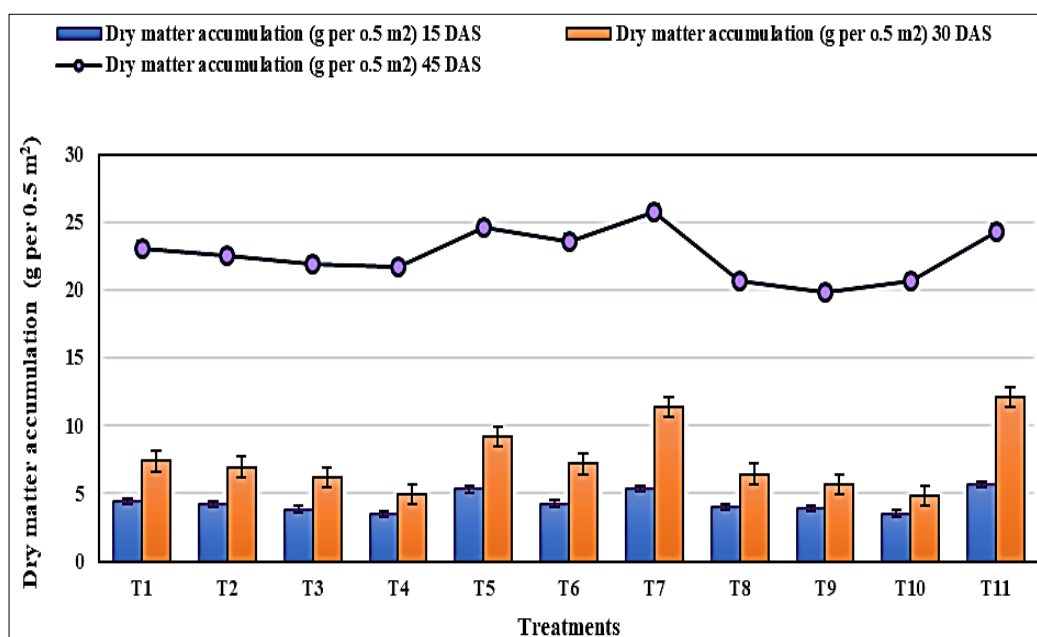
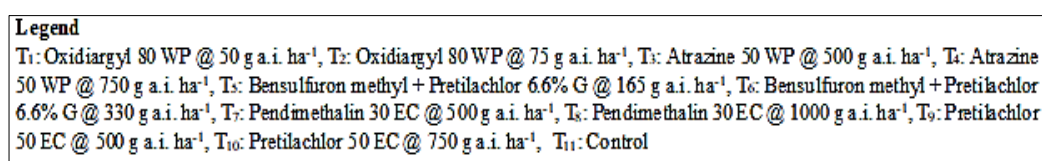


Fig 2: Dry matter accumulation in direct seeded finger millet as influenced by pre-emergence herbicides

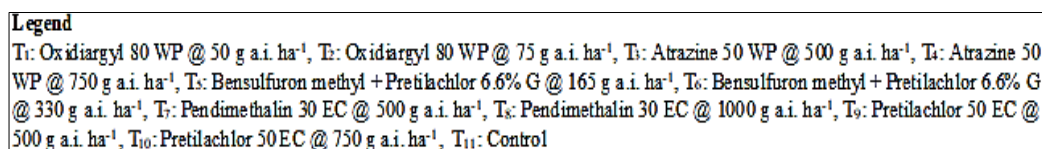
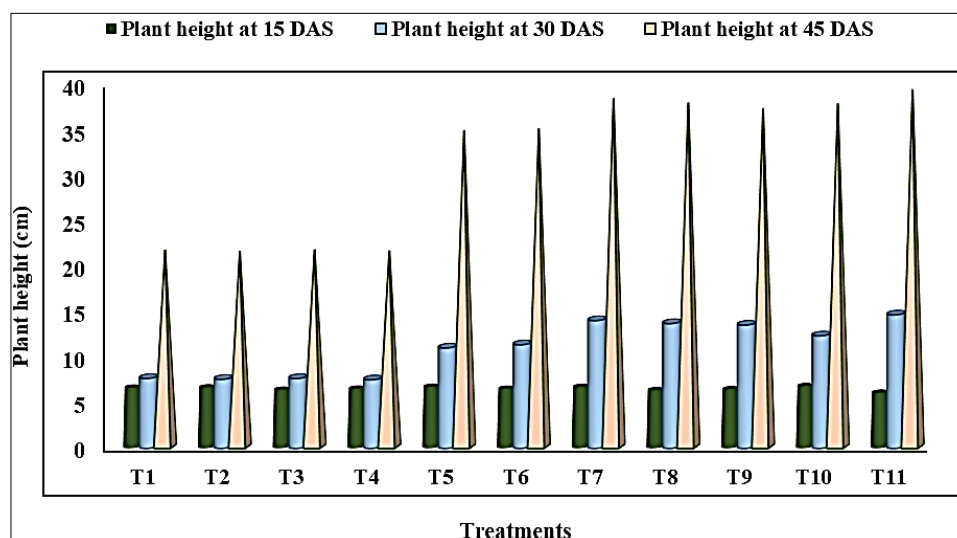
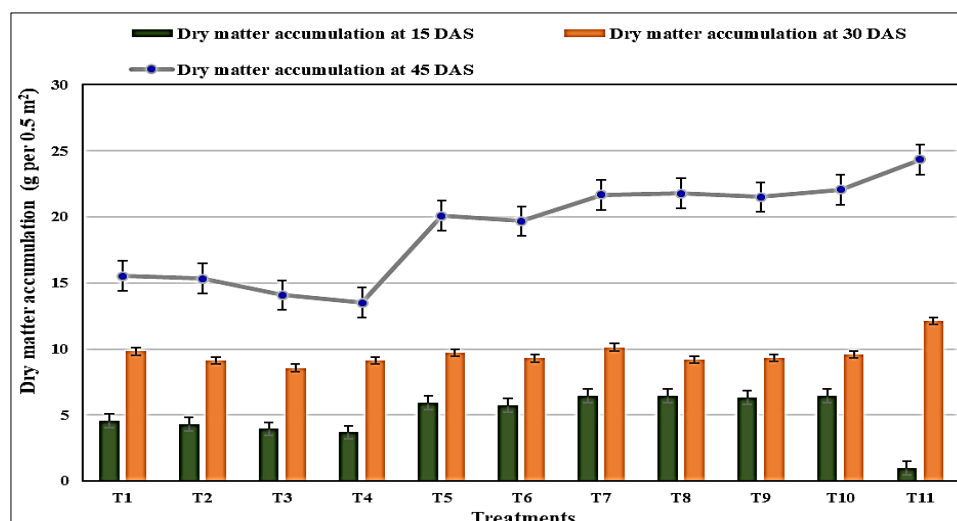
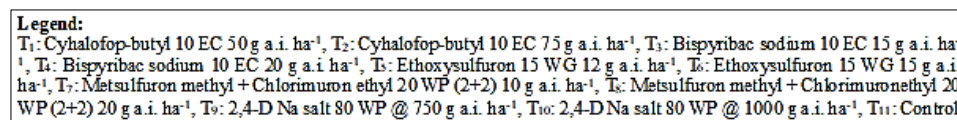
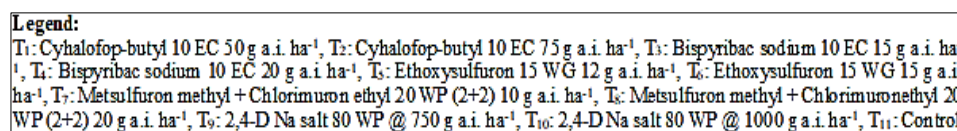


Table 3: Visual phytotoxicity ratings in the scale of 0 to 10 for direct seeded finger millet crop as influenced by post-emergence herbicides

Post-emergence herbicides	Crop phytotoxicity ratings (DAHS)									
	0	1	3	5	7	10	15	18	20	25
T ₁ : Cyhalofop- butyl 10 EC 50 g a.i. ha ⁻¹	3	3	5	5	6	6	7	7	8	8
T ₂ : Cyhalofop- butyl 10 EC 75 g a.i. ha ⁻¹	4	4	6	6	6	6	7	7	8	8
T ₃ : Bispyribac sodium 10 EC 15 g a.i. ha ⁻¹	5	5	5	6	6	6	7	7	7	7
T ₄ : Bispyribac sodium 10 EC 20 g a.i. ha ⁻¹	6	6	6	7	7	7	7	7	7	7
T ₅ : Ethoxysulfuron 15 WG 12 g a.i. ha ⁻¹	1	1	2	2	3	3	2	2	2	2
T ₆ : Ethoxysulfuron 15 WG 15 g a.i. ha ⁻¹	2	2	2	3	3	3	2	2	2	2
T ₇ : Metsulfuron methyl + Chlorimuron ethyl 20 WP (2+2) 10 g a.i. ha ⁻¹	1	1	1	1	1	1	1	1	0	0
T ₈ : Metsulfuron methyl + Chlorimuron ethyl 20 WP (2+2) 20 g a.i. ha ⁻¹	1	1	1	1	1	1	1	1	0	0
T ₉ : 2,4-D Na salt 80 WP @ 750 g a.i. ha ⁻¹	0	0	0	0	0	0	0	0	0	0
T ₁₀ : 2,4-D Na salt 80 WP @ 1000 g a.i. ha ⁻¹	0	0	0	0	0	0	0	0	0	0
T ₁₁ : Control	0	0	0	0	0	0	0	0	0	0

DAHS: Days after herbicide spray

**Fig 3:** Plant height of direct seeded finger millet as influenced by post-emergence herbicides**Fig 4:** Dry matter accumulation of direct seeded finger millet as influenced by post-emergence herbicides

Conclusion

From this study it can be concluded that, among the pre-emergence herbicides tested, pendimethalin and bensulfuron methyl +pretilachlor when used at 500 g a.i. ha⁻¹ and at 165 g a.i. ha⁻¹, respectively and among the post-emergence herbicides, Metsulfuron methyl +Chlorimuron ethyl 20 WP (2+2) and 2,4-D Na salt 80 WP when used at 20 g a.i. ha⁻¹ and at 1000 g a.i. ha⁻¹ have no phytotoxic effect on direct seeded finger millet.

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