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Performance of pre and post emergence herbicide against complex weed flora and productivity of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment entitled "Performance of pre and post emergence herbicide against complex weed flora and productivity of wheat (*Triticum aestivum* L.)" was carried out at Research Farm of Raj Mohini Devi College of Agriculture and Research Station, Ambikapur (C.G) during *Rabi* season of 2024-25. The soil of the experimental site was *Inceptisols* in nature and slightly acidic in reaction and low in available nitrogen, medium in available phosphorus and potassium. The experiment consisted of eight treatments laid out in randomized complete block design with three replications. There were eight treatment of weed management *viz* T_1 - Pendimethalin @ 750 g/ha (PE), T_2 - Pyroxasulfone @ 150 g/ha (PE), T_3 - Clodinafop @ 60 g/h (PoE), T_4 - Pendimethalin @ 750 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE), T_5 - Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE), T_6 - Clodinafop + metsulfuron @ 60+4 g/ha (PoE), T_7 - Weed free, T_8 - Weedy check. The wheat cultivar "Kanishka" was sown and harvested on 25th November 2024 to 23th March 2025. respectively.

Results of the experiment revealed that the growth and yield attributing characters of wheat like plant population m^{-1}, plant height cm, number of tillers $plant^{-1}$, dry matter accumulation g. m^{-1}, number of spike $tillers^{-1}$, number of grain $spike^{-1}$, Test weight (g), Grain yield (q ha^{-1}), Straw yield (q ha^{-1}) as well as harvest index (%) were maximum under the treatment T_7- Weed free while it was statistically followed by T_6 - Clodinafop + metsulfuron @ 60+4 g/ha (PoE) and T_5 - Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE).

In the experimental field, *Phalaris minor, Cyperus rotundus, Cynodon dactylon, Chenopodium album, Anagallis arvensis, Melilotus indica* and other some weeds were dominant. Minimum weed density & weed dry matter and also highest weed control efficiency were found under T_7- Weed free followed by T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) and T_5 - Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE). However, 57.99% reduction in yield of wheat was recorded under T_8- weedy check.

As regards to profitability of the weed management practices, maximum net return (₹ 79,437 ha^{-1}) as well as B: C ratio (2.11) was achieved under T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) followed by T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE). The highest energy input was registered under T_7- Weed free, whereas, maximum energy output and energy use efficiency observed under T_6 - Clodinafop + metsulfuron @ 60+4 g/ha (PoE).

Keywords: Wheat (*Triticum aestivum* L.), pre-emergence herbicide, post-emergence herbicide

Introduction
Wheat (*Triticum aestivum* L.) is the one of the major crops of the family Poaceae, belongs to genus *Triticum* and species *aestivum*. It is the prime staple food grain, that contains a respectable quantity of protein, niacin and thiamine. Its production requires cool and dry climate hence it is often grown in temperate zones. It occupies 217 million hectares area under cultivation with an annual production of 731 million tonnes globally. Wheat is considered as the second most important crop in India after rice, cultivated under six different agro-climatic zones in which North Western Plains Zone and the North Eastern Plains Zone are the major wheat producing zones, comprises under Indo-Gangetic Plains, followed by the Central Zone, Peninsular Zone, Northern hill zone and Southern hill zone. India ranks first in the world in terms of area and next to China in production of wheat with 30 m ha (14 percent of the world's area) cultivated area and 99.7 million tonnes (13.64%) annual production (Ramdas *et al*., 2019) [9].

The United States Department of Agriculture (USDA) estimate that world wheat production 2023-24 will be 784.43 million metric tons. China was the leading wheat producing country with production volume over 137 million metric tonnes. Second highest European union with production volume 134 million metric tonnes. Third highest India with production 114 million metric tonnes in 2023-24. In India UP comes out on the top list and is the largest wheat producing state in India. In India major wheat producing state is UP > MP > Punjab > Haryana. In Chhattisgarh data was reported at 115.300 tonnes in 2020.

Weed infestation is one of the major biotic constraints in wheat production. It is infested with diverse type of weed flora under diverse agro-climatic conditions. The yield losses due to weeds vary depending on the weed species and density as well as environmental factors. Weeds account for 37% of the total annual loss of agricultural produce in India (Yaduraju, 2006) [12]. Worldwide, herbicide is a key tool for weed management in wheat due to its cost and time effectiveness as well as effective control of some of the morphological similar weeds *(Phalaris minor* and *Avena ludoviciana*) with wheat crop. However, the excessive dependence on the herbicides has led to evolution of herbicide resistance in weeds. Globally, 19 and 74 weeds have evolved resistance against the acetyl-coA carboxylase (ACCase) and acetolactate synthase (ALS) inhibitors herbicides, respectively in wheat (Heap, 2023) [3].

Materials and Methods

The field experiment was conducted during the *Rabi*, 2024-25 at the research farm of Raj Mohini Devi College of Agriculture and Research Station, Ambikapur, (C.G.). Geographically, Ambikapur is situated at a latitude of 23º15 N, longitude of 83º14 E and altitude of 623m from mean sea level. The soil of experimental field was '*Inceptisols*' which is locally known as '*Chawar*'. The soil was slightly acidic (pH 6.2) in nature with medium in fertility having 0.37% soil organic carbon, low N (258 kg ha^{-1}), medium P_2O_5 (12.2 kg ha^{-1}) and medium K_2O (308 kg ha^{-1}).

The experiment was laid out in a randomized block design with three replications. The study consisted of eight treatment, *viz*, T_1- Pendimethalin @ 750 g/ha (PE), T_2- Pyroxasulfone @ 150 g/ha (PE), T_3- Clodinafop @ 60 g/h (PoE), T_4- Pendimethalin @ 750 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE), T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE), T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE), T_7- Weed free and T_8- Weedy check. The herbicides were applied as per the treatments.

Results and Discussion

Weed flora identification (m^{-2})

The principal weeds found in the field were *Phalaris minor* (11.24%), *Cyperus rotundus* (29.33%), *Cynodon dactylon (*7.05%), *Chenopodium album (*9.90%), *Anagallis arvensis* (7.05%), *Melilotus indica (*15.62%*)* and others weeds like- *Rumex dentatus, Fumaria parviflora, Vicia sativa, Avena ludoviciana, Spergula arvensis* contributed (19.81%).

Density of Total weed (No. m^{-2})

Weed management practices had a significant influence on total weed density at all observation intervals 30, 60, and 90 DAS (Table 1). The highest weed density was recorded in T_8- Weedy check with values of (154.33, 175 and 162.67 plant m^{-2}), respectively. In contrast, the lowest total weed density was observed in the T_7- Weed free, with only (0 plant m^{-2}) at all growth stages, respectively. This was followed closely by the treatment T_5- Pyroxasulfone @ 150 g/ha (PE) fb Clodinafop @ 60 g/h (PoE), which recorded (22.67, 24.67, and 21.67 plant m^{-2}) at the corresponding intervals. Interestingly, the tank mix T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) also showed promising control at later stages, recording (16.67 and 14.00 m^{-2}) at 60 and 90 DAS, respectively, despite a higher density at 30 DAS (128.00 m^{-2}). Overall, T_2- Pyroxasulfone @ 150 g/ha (PE) and T_1- Pendimethalin @ 750 g/ha (PE) application when followed by post-emergence herbicides and manual weeding, proved significantly more effective in reducing total weed densities compared to single applications. Related finding was also reported by Meena and Singh (2011) [5].

Dry weight of total weeds (No. m^{-2})

The T_7- Weed free treatment consistently recorded the lowest dry weight (0.00 g m^{-2}) at 30, 60, and 90 DAS (Table 1), indicating complete weed suppression. T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) was the most effective herbicide treatment, with the lowest dry weights among herbicide treatments (2.90 g m^{-2}) at 30 DAS, the combination of pre-emergence (PE) and post-emergence (PoE) herbicides likely provided comprehensive control by targeting weeds at 30 DAS. T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) was highly effective at later stages, recording (12.44 and 15.99 g m^{-2}) at 60 and 90 DAS, making it the second most effective herbicide treatment, particularly for post-emergence control T_8- Weedy check recorded the highest dry weights at all intervals (48.13, 151.56 and 189.00 g m^{-2}) at 30, 60 and 90 DAS. T_2- Pyroxasulfone @ 150 g/ha (PE) showed strong early control at 30, 60 and 90 DAS (4.40, 24.37 and 35.29 g m^{-2}). T_3- Clodinafop @ 60 g/h (PoE) and T_1- Pendimethalin @ 750 g/ha (PE) were less effective, with higher dry weights, particularly at 90 DAS (48.92 and 92.53 g m^{-2}), indicating limited long-term control. Related finding was also reported by Paighan *et al*., (2013) [6], Meena and Singh (2011) [5].

Weed control efficiency (%)

Weed control efficiency of Weed free was the highest over the rest of the treatments at all the periods of observation, recording 100% at all growth period (Table 1 & Fig 1). Among the herbicidal treatments, the highest WCE was observed with T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE), which recorded 93.97% at 30 DAS. and T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) which recorded 91.79 and 91.58 at 60 and 90 DAS. followed closely by T_2- Pyroxasulfone @ 150 g/ha (PE) with 90.86% at 30 DAS. and T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) with 90.40% and 88.68% at 60 and 90 DAS T_1- Pendimethalin @ 750 g/ha (PE), showed comparatively reduced values 65.84%, 61.90% and 51.27% throughout the crop growth period. T_8- Weedy check consistently recorded 0% WCE**,** indicating no weed suppression in the absence of control measures. Related finding was also reported by Rahaman and Mukherjee (2009) [8], Pisal and Sagarka (2013) [7].

Weed index (%)

In the present investigation, the lowest weed index (0.0%) was observed under Weed free indicating its complete effectiveness in suppressing weed competition and achieving maximum yield potential (Table 1 & Fig 1). Among the herbicidal treatments, T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) recorded the lowest weed index of 6.81%, followed by T_5- Pyroxasulfone @ 150 g/ha (PE) fb Clodinafop @ 60 g/h (PoE) 8.81%, T_2- Pyroxasulfone @ 150 g/ha (PE) 16% and T_3- Clodinafop @ 60 g/h (PoE) 23.87%. Related finding was also reported by Sharma

(2009) [10].

Crop Studies

Number of tillers plant-1

The number of tillers plant-1 at harvest was significantly influenced by the weed management practices employed (Table 2). While plant population remained statistically similar across treatments, the variation in tillering reflects the degree of weed suppression and the availability of resources (light, nutrients, space) for crop growth. The highest number of tillers per plant was recorded in the T_7- Weed free plot with 5.67 tillers, which was significantly superior to all other treatments. allowing the crop to utilize resources fully, thereby promoting more effective tiller production. Among herbicide treatments, T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) followed closely with 5.00 tillers plant-1, which was statistically at par with T_5-Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) and T_2- Pyroxasulfone @ 150 g/ha (PE), recording 4.67 and 4.33 tillers, respectively. The lowest number of tillers 2.00 was recorded in the T_8- Weedy check, which was significantly lower than all other treatments. Continuous weed pressure likely hindered tiller formation by competing with the crop for essential growth factors. Related finding was also reported by Bharat and Kachroo (2007) [2].

No. of spike plant-1

The number of spikes plant-1 differed significantly across treatments (Table 2). The maximum number of spikes 5.33 was recorded in the T_7- Weed free treatment which was significantly superior to all other treatments. Among herbicidal treatments, T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) showed 4.67 spikes plant-1, which was statistically at par with T_5-Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) 4.33, T_2- Pyroxasulfone @ 150 g/ha (PE) and T_4- Pendimethalin @ 750 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) 4.00 each. The minimum number of spikes was recorded in the T_8- Weedy check at 1.67, highlighting the severe negative impact of weedy weed competition on productive tiller formation. Related finding was also reported by Kaur *et al*., (2015).

Number of grains spike-1

The number of grain spike-1 differed significantly across treatments (Table 2). The T_7- weed free plot recorded the highest value of 44.67 grains spike-1, followed by T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) 41.33 and T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) 40.00, indicating better resource availability and pollination efficiency under effective weed control. The lowest grain counts 30.33 was recorded in T_8- Weedy check, reaffirming the suppressive effect of weeds on reproductive development. Related finding was also reported by Meena and Singh (2011) [5].

1000 - Seed weight (g)

The Test weight differed significantly across treatments (Table 2) influenced by weed management. The maximum 1000-seed weight was recorded in T_7- weed free 42.47 g, followed by T_6-Clodinafop + metsulfuron @ 60+4 g/ha (PoE) 41.30 g and T_1-Pendimethalin @ 750 g/ha (PE) 41.20 g. Interestingly, despite its poor performance in yield, T_1- Pendimethalin @ 750 g/ha (PE) had a relatively high test weight, possibly due to a reduced number of grains plant-1 leading to more resource allocation grain-1. The lowest test weight was observed in T_8- weedy check 38.10 g. Related finding was also reported by Meena and Singh (2011) [5].

Seed yield (q ha-1)

The Seed yield differed significantly across treatments (Table 2) was significantly influenced by weed management practices. The highest grain yield 52.45 q ha-1 was obtained from T_7- weed free, which was significantly higher than all herbicide-based treatments. Among the herbicidal treatments, T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) recorded 48.88 q ha-1, followed by T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) 47.83 q ha-1 and T_2- Pyroxasulfone @ 150 g/ha (PE) 44.06 q ha-1. These results underscore the benefit of broad-spectrum or sequential weed control strategies. The lowest seed yield 22.03 q ha-1 was observed in the T_8- weedy check, demonstrating a substantial yield reduction due to intense weed-crop competition. Related finding was also reported by Pisal and Sagarka (2013) [7].

Straw yield (q ha-1)

The Straw yield differed significantly across treatments (Table 2) followed the similar trend. The maximum straw yield 45.80 q ha-1 was recorded in T_7- Weed free, followed by T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) 42.94 q ha-1 and T_5-Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) 42.71 q ha-1. Even the T_8- weedy check recorded 39.19 q ha-1, indicating that weed presence does not drastically reduce vegetative biomass, but rather affects reproductive output more significantly. Related finding was also reported by Rahaman and Mukherjee (2009) [8], Pisal and Sagarka (2013) [7].

Harvest index (%)

The Harvest index differed significantly across treatments (Table 2) though not significantly influenced by treatments, still showed a favorable trend under effective weed control. The highest Harvesting index was recorded in T_7- weed free 53.37%, followed closely by T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) 53.23% and T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) 52.83%, indicating more efficient conversion of biomass into grain yield. The lowest Harvest index 36.00% was noted in T_8- weedy check, reflecting poor reproductive output relative to total biomass, due to intense weed competition.

Economics

Gross return (₹ ha-1)

Gross returns mirrored the yield performance of treatments. The highest gross return (₹ 1,17,049 ha-1) was recorded in T_7- Weed free, due to maximum grain and straw yield. Among the herbicidal options, T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) (₹ 1,11,202 ha-1) and T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) (₹ 1,08,813 ha-1) performed exceptionally well, clearly indicating the positive economic impact of effective and integrated weed control strategies. In contrast, T_8- Weedy check resulted in the lowest gross return (₹ 50,126 ha-1) due to significant yield losses under unmanaged weed competition.

Net return (₹ ha-1)

Net returns, a direct measure of profitability, followed a similar trend. The T_7- weed free plot produced the maximum net return (₹ 81,513 ha-1), closely followed by T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE) (₹ 78,059 ha-1) and T_5-Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) (₹ 76,235 ha-1). Despite slightly higher cultivation costs, these treatments delivered strong economic performance due to substantial increases in productivity. On the other hand, T_8-

Weedy check recorded the lowest net return (₹ 19,780 ha^{-1}), demonstrating that failure to control weeds severely reduces profitability, even when input costs are minimal. Related finding was also reported by Singh *et al.*, (2005) [11].

Benefit - cost ratio

The B:C ratio offers a comprehensive measure of economic efficiency. The highest B:C ratio 2.36 was observed in T_6- Clodinafop + metsulfuron @ 60+4 g/ha (PoE), followed by T_5- Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE) 2.34 and T_7- Weed free 2.29. This highlights the cost-effectiveness of well-planned herbicide applications and integrated weed management practices. T_2- Pyroxasulfone @ 150 g/ha (PE) also showed a strong B:C ratio of 2.14, indicating that even single herbicide applications, when effective, can be economically viable. The lowest B:C ratio 0.65 was recorded in the T_8- weedy check confirming that weed infestation severely compromises economic returns, regardless of low input costs. Related finding was also reported by Raj *et al.*, (2020), Paighan *et al.*, (2013) [6].

Table 1: Density and dry weight of total weeds (No. m^{-2}), Weed control efficiency% and Weed index% as influenced by different weed management practices

Treatments	Weed density of total weed			Dry weight of total weeds			Weed control efficiency %			Weed index %
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	
T_1 - Pendimethalin @ 750 g/ha (PE)	8.86 (78.00)	9.70 (93.67)	9.55 (90.67)	4.12 (16.44)	7.73 (59.26)	9.65 (92.53)	65.84	61.08	52.07	31.15
T_2 - Pyroxasulfone @ 150 g/ha (PE)	5.55 (30.33)	6.56 (42.60)	6.26 (38.67)	2.21 (4.40)	4.99 (24.37)	6.07 (35.29)	90.86	83.99	81.25	16.00
T_3 - Clodinafop @ 60 g/h (PoE)	11.67 (135.67)	7.25 (52)	6.82 (46)	6.23 (38.36)	6.18 (37.67)	7.03 (48.92)	20.29	75.26	74.51	23.87
T_4 - Pendimethalin @ 750 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE)	6.67 (44.00)	6.70 (44.33)	6.26 (38.67)	2.60 (6.27)	5.28 (27.43)	6.33 (39.57)	86.98	81.99	79.97	42.30
T_5 - Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE)	4.81 (22.67)	5.02 (24.67)	4.74 (22)	1.84 (2.90)	3.88 (14.54)	4.69 (21.50)	93.97	90.45	88.96	8.81
T_6 - Clodinafop + metsulfuron @ 60+4 g/ha (PoE)	11.34 (128)	4.14 (16.67)	3.81 (14)	5.94 (34.73)	3.60 (12.44)	4.06 (15.99)	27.83	91.83	91.93	6.81
T_7 - Weed free	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	100.00	100.00	100.00	0.00
T_8 - Weedy check	12.44 (154.33)	13.25 (175)	12.77 (162.67)	6.97 (48.13)	12.33 (151.56)	13.80 (189.90)	0.00	0.00	0.00	57.99
SEm (±)	0.61	0.47	0.38	0.10	0.35	0.43	-	-	-	-
CD (P=0.05)	1.84	1.43	1.15	0.29	1.07	1.31	-	-	-	-

*Values in parentheses are original. **Values transformed by ($\sqrt{x + 0.5}$)

Table 2: Yield attributes and economics of wheat as influenced by different weed management practices

Treatments	No. of tillers plant^{-1}	No. of spike plant^{-1}	No. of grains spike^{-1}	1000- Seed weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C ratio
T_1 - Pendimethalin @ 750 g/ha (PE)	3.00	2.67	36.00	41.20	36.11	41.11	46.76	82,150	49,959	1.55
T_2 - Pyroxasulfone @ 150 g/ha (PE)	4.33	4.00	39.00	41.15	44.06	41.56	51.46	1,00,237	68,353	2.14
T_3 - Clodinafop @ 60 g/h (PoE)	4.00	3.67	37.33	37.20	39.93	41.26	49.18	90,841	59,483	1.90
T_4 - Pendimethalin @ 750 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE)	4.33	4.00	38.67	36.93	43.13	41.38	51.04	98,121	65,263	1.99
T_5 - Pyroxasulfone @ 150 g/ha (PE) *fb* Clodinafop @ 60 g/h (PoE)	4.67	4.33	40.00	38.12	47.83	42.71	52.83	1,08,813	76,235	2.34
T_6 - Clodinafop + metsulfuron @ 60+4 g/ha (PoE)	5.00	4.67	41.33	41.30	48.88	42.94	53.23	1,11,202	78,059	2.36
T_7 - Weed free	5.67	5.33	44.67	42.47	52.45	45.80	53.37	1,17,049	81,513	2.29
T_8 - Weedy check	2.00	1.67	30.33	38.10	22.03	39.19	36	50,126	19,780	0.65
SEm (±)	0.13	0.15	0.14	0.12	0.21	0.02	1.93	534.54	617.21	0.02
CD (P=0.05)	0.38	0.46	0.42	0.36	0.62	0.05	NS	1621.31	1872.12	0.07

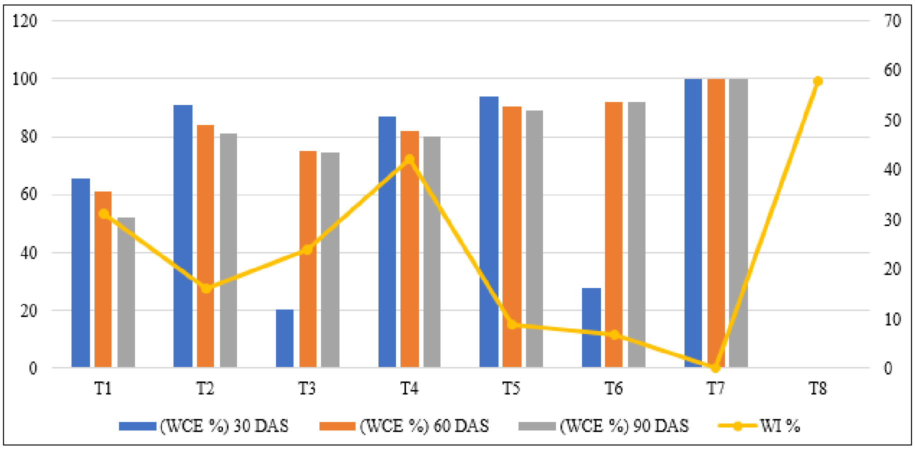

Fig 1: WCE and WI

Fig 2: Different stages of wheat cultivation and field observation: (a) Land preparation and sowing; (b) Early crop establishment and weeding; (c) Crop growth stage with field monitoring; (d) Data recording during maturity stage

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