

Comparative efficacy of different herbicidal combinations on weed growth and yield attributes of wheat

ABSTRACT

Weeds are the main biotic obstacles on wheat production, which can impair wheat productivity by up to 60%, if not handled under critical stages of crop life cycle. Chemical weed control through herbicides has been the most popular and effective method among farmers. The weed management using similar herbicides however has led to herbicide resistance in weeds. This requires the evaluation of newer herbicidal combinations for the control of weeds in wheat. Therefore, an experiment was conducted at Research Farm, Department of Agronomy, JNKVV, Jabalpur, Madhya Pradesh during the *Rabi* season of 2016-17 to evaluate the effect of post emergence application of herbicides on the weeds and yield of wheat. The experiment was laid out in randomized block design with ten treatments comprising of eight herbicidal combinations along with a hand weeding and a weed check and replicated thrice. Observations on different weed parameters, growth parameters and yield of wheat were recorded. Among the different herbicidal combinations, the post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha resulted in greatest suppression of weeds and had highest weed control efficiency (56.73%). It also led to highest growth in wheat which resulted in highest grain yield (5.81 t/ha) and harvest index (44.99%). From this study, it can be concluded that the post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha can not only control weeds effectively but also increase the yield of wheat.

Keywords: Florasulam, Grain yield, Halauxifen-methyl ester, Harvest index, Weed control efficiency, Wheat

1. INTRODUCTION

“Wheat (*Triticum aestivum* L.) is one of the most important cereal crops occupying the prime position among food crops in the world” [1]. “It is the most significant grain crop, both historically and as a source of human nourishment” [2]. “In India, it is the second important food crops being next to the rice. Wheat is a staple food for over one billion people in 43 nations around the world. It accounts for around 20% of total dietary calories consumed by humans” [3]. “Wheat is farmed on around 220

million hectares worldwide, with approximately half of that area in developing nations. In 2019–20, wheat was grown in India on an area of about 31.45 million hectares with a production of 107.59 million tonnes" [4]. "In Madhya Pradesh, wheat is produced on about 10.02 million hectares, producing 16.52 million tonnes of grain with a productivity of 3298 kg/ha" [5]. Hence, it is important to increase the yield of wheat particularly in irrigated areas of Madhya Pradesh.

There are many factors which is affected crop output under changing climatic conditions [6, 7] but one of the formidable factors that limit the crop productivity is severe weed infestation [8, 9]. "Weeds have a habit to shift with the alteration in tillage, agronomic management, and cropping system although there are other factors that govern the alterations in the weed flora" [10, 11]. "Although being a serious problem in crop field, this problem always remains under-estimated although they cause higher reduction in economic yield of crops than other pests and diseases" [12, 13]. "Weeds are a major barrier to maintaining wheat production and productivity levels" [14, 15]. "The critical period of crop weed competition in wheat crop is 11- 21 days after crop emerged [16] and reduction of grain yield in late sown wheat was reported up to 34.3% due to mixed weed flora" [17].

"Manual weed control is regarded as the best and sustainable weed management option; however, increasing costs and labour shortage have rendered this technique ineffective" [18, 19]. "Hiking costs of manual weed control have forced farmers to adopt alternative weed management strategies" [20, 21]. "Weed management with herbicides is an easiest and most successful method" [22, 23]. "Herbicides have played a significant role in modern agriculture for weed management" [24, 25]. "Thus, for sustainable weed control, adopting herbicide application techniques may be an effective and economic weed control strategy" [26, 27]. "Many herbicides are being used for effective control of weeds in wheat but their weed control efficacy is affected to great extent by the climatic condition at the time of application of almost all herbicides whether applied as pre emergence or post emergence" [28]. "In such a crisis, herbicides with different modes of action, such as pendimethalin (pre-emergence) and metribuzin (pre-emergence or post-emergence) alone and in sequential or tank mix combination with post-emergence herbicides sulfosulfuron and clodinafop, pinoxaden, could be viable options" [29]. Metsulfuron and Sulfosulfuron are the most widely used herbicides in wheat for effective control of weeds but sometimes they have not been effective due to resistance to weeds. Hence, the present investigation was proposed to compare the new post emergence herbicides i.e. halauxifen-

methyl ester + florasulam with the existing ones to find out the best herbicidal combination for controlling diverse weed flora of wheat.

2. MATERIALS AND METHODS

A field experiment was carried out at the Research Farm, Department of Agronomy, JNKVV, Jabalpur, Madhya Pradesh during the *Rabi* season of 2016-17. Soil of the experimental area is clayey in texture, neutral in reaction (pH 7.3), medium in organic carbon content (0.64%), normal in electrical conductivity (0.32 ds/m), medium in available N (370.0 kg/ha), available P (16.0 kg /ha) and high in available K (298 kg/ha). Physio-chemical Properties of the soil are given in Table 1. Ten treatments consisted with post emergence application of halauxifen-methyl ester + florasulam at 7.6 g/ha (T₁), halauxifen-methyl ester + florasulam at 10.20 g/ha (T₂), halauxifen-methyl ester + florasulam at 12.70 g/ha (T₃), halauxifen-methyl ester + florasulam at 25.50 g/ha (T₄) and mesosulfuron + Iodosulfuron at 14.40 g/ha (T₅), sulfosulfuron + metsulfuron methyl at 32.0 g/ha (T₆), metsulfuron + clodinafop propargyl at 10.00 g/ha (T₇), metsulfuron-methyl at 4 g/ha (T₈) along with a hand weeding (T₉) and weedy check(T₁₀), were tested in randomized block design with three replications. Sowing of the experiment was done on December 1, 2016 in 5.00 x 3.60 m plot size with seed rate of 100 kg/ha by drilling in rows 22.5 cm apart. A uniform dose of 120 kg N, 60 kg P₂O₅ and 40 kg K₂O/ha was given in the experimental plots through urea, single super phosphate and muriate of potash, respectively. Five irrigation were given to the crop at all the critical stages viz., crown root initiation, maximum tillering, late jointing, flowering and milk stage. Different studies were made during the course of investigation pertaining to weed and crop parameters. The quadrat of 0.25/m² (0.5 m x 0.5 m) was randomly thrown at four places in each plot and then it was marked by fixing wooden stick for subsequent observation. Species wise weed count and total number of weeds per meter square were recorded. The percentage composition of weed flora was estimated from weedy check. Growth parameters viz. plant height, tillers/m² were recorded at 60 DAS. Yield attributing characters viz., grains/ear head was recorded. Harvesting was done when the panicle matured and plant was dried up. The threshing of the crop was done by manually by plot wise and grain and straw were conducted separately. The grain yield was recorded as kg/plot and then conducted into t/ha.

Table 1. Physio-chemical Properties of the soil in the experimental field

S. No.	Particular	Values	Class/Groups	Method used
A.	Mechanical composition			
1.	Sand (%)	25.189	Clay	International pipette method [30]
2.	Silt (%)	19.18		
3.	Clay (%)	55.64		
B.	Chemicals Compositions			
1.	Organic carbon (%)	0.64	Medium	Walkey and Black rapid titration Method [31]
2.	Available N (kg/ha)	370	Medium	Alkaline permanganate method [32]
3.	Available P (kg/ha)	16	Medium	Calorimetric method [33]
4.	Available K (kg/ha)	298	High	Flame photometer method [34]
5.	Soil PH (1:2:5 Soil water ratio)	7.3	Neutral	Glass electrode pH meter [30]
6.	Electrical conductivity (ds/m at 25 °C)	0.32	Normal	Sole-Bridge method [35]

3. RESULTS AND DISCUSSION

3.1 Effect on weeds

In the experimental field, dominated weeds viz. *Phalaris minor*, *Medicago denticulate*, *Cichorium intybus*, *Chenopodium album*, *Anagalis arvensis* and *Convolvulus arvensis* were found. Similar weed species were also reported by [36, 37].

Weed control treatments had significant influence on the weed density and dry weight during the course of field experimentation (Table 2 & 3). The density and dry weight of predominant weeds were found maximum under weedy check plots due to uninterrupted growth of weeds from germination up to the end of critical period of crop-weed competition (i.e. 45 DAS) [38]. But the density of predominant weeds and their dry weight reduced identically in plots receiving either herbicidal or mechanical weed control. The post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha curbed the weed growth to that of significant reduction in broadleaf weeds as well as grassy followed by halauxifen-methyl ester + florasulam at 7.6 g/ha and halauxifen-methyl ester + florasulam at 10.2 g/ha after the 60 days of application of former herbicides [39]. These herbicides gave satisfactory control of both the broad leaved weeds and annual grassy weed was better control weed like *Phalaris minor*, *Medicago denticulate*, *Cichorium intybus*, *Chenopodium album*, *Anagalis arvensis* and *Convolvulus arvensis*. Better activity of these herbicides against both broad leaved weeds could be assigned the reason for lower density and dry weight of the weeds. However, the hand weeding excelled to all the herbicidal treatments in reducing the population of weeds. These were due to complete elimination of weeds from the wheat field [40, 41]. Halauxifen-methyl is considered to mimic plant growth hormone auxin, resulting in the disruption of growth processes in

susceptible plants. Cellular effects include alterations in cell wall elasticity and gene expression. Additionally, non-productive tissue growth is induced, resulting in epinasty and phloem disruption, preventing the movement of photosynthates and causing death in days to weeks [42].

Table 2. Influence of different herbicidal treatments on weed density (no./m²) at 60 DAA in wheat

Treatments	<i>Phalaris minor</i>	<i>Medicago denticulata</i>	<i>Cichorium intybus</i>	<i>Chenopodium album</i>	<i>Anagalis arvensis</i>	<i>Convolvulus arvensis</i>
T ₁ - Halauxifen methyl ester + florasulam at 7.6 g/ha	2.57 (6.13)	2.16 (6.18)	2.28 (4.70)	2.14 (4.80)	2.81 (7.42)	2.71 (6.84)
T ₂ - Halauxifen-methyl ester + florasulam at 10.20 g/ha	2.18 (4.08)	2.27 (4.44)	2.22 (4.42)	2.20 (4.34)	2.64 (5.48)	2.25 (4.58)
T ₃ - Halauxifen-methyl ester + florasulam at 12.70 g/ha	2.14 (4.10)	2.26 (4.62)	2.42 (5.35)	2.16 (4.48)	2.18 (5.57)	2.24 (4.62)
T ₄ - Halauxifen-methyl ester + florasulam at 25.50 g/ha	2.13 (4.12)	2.23 (4.78)	2.50 (5.76)	2.28 (4.72)	2.51 (5.82)	2.30 (4.78)
T ₅ - Mesosulfuron + Iodosulfuron at 14.40 g/ha	2.59 (6.22)	2.91 (7.94)	2.70 (6.81)	2.22 (5.44)	3.21 (9.79)	2.73 (6.95)
T ₆ - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha	2.59 (6.22)	2.70 (6.80)	3.19 (9.68)	2.17 (5.22)	2.73 (6.94)	2.69 (6.72)
T ₇ - Metsulfuron + clodinafoppropargyl at 10.0 g/ha	2.69 (6.74)	2.70 (6.80)	2.99 (8.46)	2.31 (5.84)	2.73 (6.96)	2.73 (6.94)
T ₈ - Metsulfuron- methyl at 4.0 g/ha	2.95 (8.23)	1.95 (4.30)	2.28 (4.72)	2.25 (5.56)	2.53 (5.88)	2.75 (7.04)
T ₉ - Hand weeding 30 DAS	2.13 (4.04)	2.66 (3.60)	2.31 (4.14)	1.98 (3.42)	2.40 (4.26)	2.20 (4.33)
T ₁₀ - Weedy check	3.13 (9.32)	4.10 (16.34)	3.11 (9.16)	2.99 (8.46)	3.12 (9.26)	2.97 (8.34)
SEm±	0.09	0.09	0.14	0.10	0.09	0.08
CD at 5 %	0.27	0.27	0.42	0.30	0.27	0.24

Table 3. Influence of different herbicidal treatments on weed dry weight (g/m²) at 60 DAA in wheat

Treatments	<i>Phalaris minor</i>	<i>Medicago denticulata</i>	<i>Cichorium intybus</i>	<i>Chenopodium album</i>	<i>Anagalis arvensis</i>	<i>Convolvulus arvensis</i>
T ₁ - Halauxifen methyl ester + florasulam at 7.6 g/ha	2.93 (8.09)	1.91 (4.54)	1.33 (1.47)	1.67 (2.30)	1.67 (2.30)	1.89 (3.08)
T ₂ - Halauxifen-methyl ester + florasulam at 10.20 g/ha	2.47 (5.35)	1.73 (5.48)	1.30 (1.31)	1.71 (2.43)	1.58 (2.01)	1.60 (2.06)
T ₃ - Halauxifen-methyl ester + florasulam at 12.70 g/ha	2.43 (5.39)	1.99 (3.46)	1.39 (1.44)	1.69 (2.34)	1.35 (1.32)	1.59 (2.03)
T ₄ - Halauxifen-methyl ester + florasulam at 25.50 g/ha	2.42 (5.60)	1.96 (4.48)	1.44 (1.56)	1.77 (2.64)	1.52 (1.80)	1.63 (2.15)
T ₅ - Mesosulfuron + Iodosulfuron at 14.40 g/ha	2.95 (8.21)	2.54 (5.96)	1.53 (1.84)	1.73 (2.49)	1.88 (3.03)	1.91 (3.13)
T ₆ - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha	2.95 (8.21)	2.37 (5.10)	1.76 (2.61)	1.69 (2.36)	1.63 (2.15)	1.88 (3.02)
T ₇ - Metsulfuron + clodinafoppropargyl at 10.0	3.07 (8.90)	2.37 (5.10)	1.67 (2.28)	1.79 (2.71)	1.63 (2.16)	1.90 (3.12)

g/ha						
T ₈ - Metsulfuron- methyl at 4.0 g/ha	3.37 (10.86)	1.99 (4.36)	1.33 (1.80)	1.75 (2.55)	1.52 (1.82)	1.92 (3.17)
T ₉ - Hand weeding 30 DAS	2.41 (4.33)	2.33 (3.95)	1.35 (1.19)	1.56 (1.92)	1.46 (1.63)	1.57 (1.95)
T ₁₀ - Weedy check	3.58 (12.30)	3.57 (12.26)	1.72 (2.47)	2.29 (4.74)	1.84 (2.87)	2.06 (3.75)
SEm±	0.09	0.08	0.09	0.08	0.09	0.07
CD at 5 %	0.26	0.23	0.27	0.24	0.28	0.20

The weed control efficiency of different treatments varied markedly due to weed control practices (Figure 1). The weed control efficiency of halauxifen-methyl ester + florasulam at 7.6 g/ha, sulfosulfuron + metsulfuron methyl at 32.0 g/ha, metsulfuron + clodinafop at 10 g/ha and metsulfuron-methyl at 4 g/ha was poor (43.19, 46.77, 46.98 and 34.35%) as these herbicides didn't killed both grassy and broad leaved weeds. The application of metsulfuron alone given minimum weed control efficiency (34.35%) where as it was increased when the combined application of different herbicides. The combined application of halauxifen-methyl ester + florasulam at (10.20 g/ha) recorded maximum weed control efficiency (56.73%) followed by halauxifen-methyl ester + florasulam at 12.70 g/ha and halauxifen-methyl ester + florasulam at 25.50 g/ha. However, these herbicidal treatments did not surpass hand weeding, which had the maximum weed control efficiency (56.97) and proved superior over herbicidal treatments. It was due to complete eliminating all the weeds during critical period of crop weed competition in irrigated wheat (30-45 DAS) [43, 44, 45].

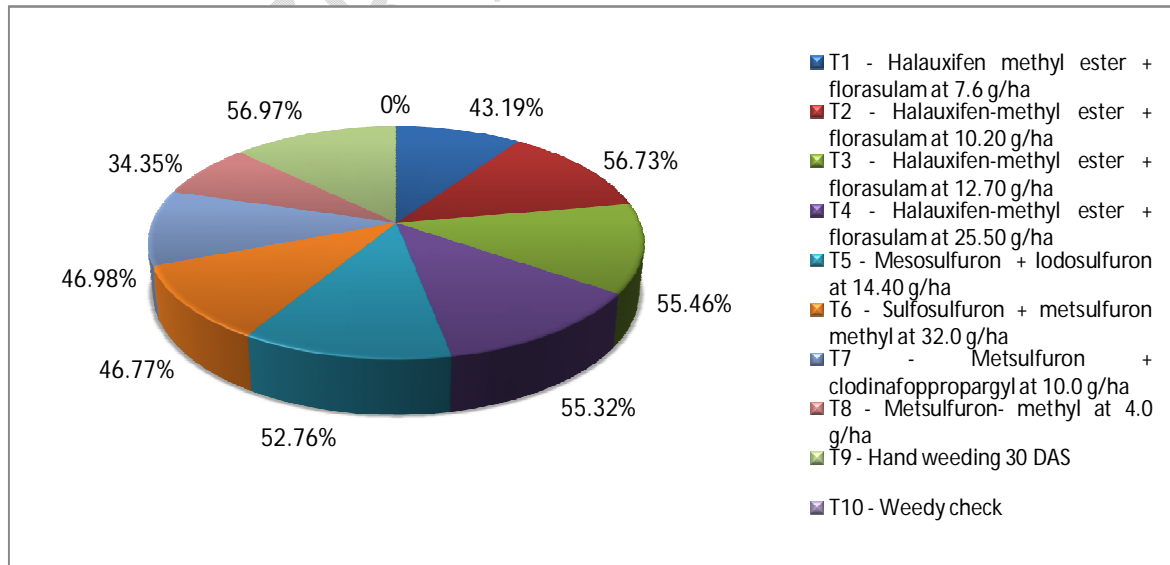


Figure 1. Influence of different herbicidal treatments on weed control efficiency (%) at 60 DAA in wheat

3.2 Effect on crop

The effect of weed control treatments on growth parameters viz., plant height and number of tillers/m² was found significant at 60 DAS (Table 4). Weedy check plots had significantly minimum values of growth parameters from early growth period up to advanced growth stages due to severe crop-weed competition for growth resources leading to poor values of growth parameters. There was identical improvement in above parameters in plots receiving herbicidal treatments including hand weeding. Among the herbicidal treatments, application of halauxifen-methyl ester + florasulam at 10.20 g/ha recorded the higher plant height (66.47 cm) and number of tillers/m² (415.47). It was due to lesser crop-weed competition in this treatment led to proper root and shoot growth. These results attained the superior values of growth parameters. However, none of the herbicidal treatments surpass hand weeding as this treatment recorded the maximum values of plant height and number of tillers/m². These findings are in conforming to the findings of [46]. Complete elimination of all weeds might have avoided the competetional stress and have prevailed congenial environment for better root and shoot growth. Henceforth, maximum values of these parameters were recorded under hand weeding [47].

Yield attributing trait i.e. grains per ear head was significantly influenced by different weed control treatments (Table 4). The values grains per ear head were minimum under weedy check plots due to poor growth parameters [48]. But there was appreciable improvement in this parameter in plots receiving herbicidal including mechanical weed control. Post emergence application of halauxifen-methyl ester + florasulam at 7.6 g/ha was found significantly superior and registered the higher value of grains per earhead (51.17) as compare to other remaining herbicidal treatments and at par to halauxifen-methyl ester + florasulam at 12.70 g/ha. However, none of the herbicidal treatments excelled to hand weeding which had the maximum value of grains per ear head [49]. The better growth and development of crop plants under aforesaid treatments on account of better control of weeds could be assigned the reason for better yield attributing trait under herbicidal treatments and complete weed free environment under hand weeding during critical period of crop-weed competition, led to record superior values of growth parameters, which in turn recorded the maximum values of yield attributing trait [50, 51].

Grain yield of wheat varied significantly due to different weed control treatments (Table 4). The grain yield was recorded minimum under weedy plots (3.01 t/ha), where weeds were allowed to grow throughout the crop season. Due to which poor values of growth parameters and yield attributing traits were recorded. These situations results into lower grain yield. While maximum grain yield was

recorded under hand weeding treatment and it surpassed all the herbicidal treatments in terms of grain yields due to the superior values of yield attributing traits [52]. Among the herbicidal treatments, post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha caused significant impressment in grain yield and recorded the higher grain yield (5.81 t/ha) *fb* halauxifen-methyl ester + florasulam at 12.70 g/ha. It was due to effective weed control with the herbicidal application which provide weed free environment to crop plant for the growth and development [53, 54]. **Weed control brought down competition and created congenial micro-environment for better establishment and growth of wheat crop. The herbicide sequence comprising halauxifen + florasulam increased grain yield and its better weed control provided all favourable conditions like increased availability of nutrients, moisture, light and other factors to the crop which in turn resulted in higher dry matter production [55].**

Harvest index of different weed control treatments was calculated and given in Table 4. The Post emergence application of all the herbicidal treatment recorded higher harvest index over weedy check plots. The higher value of harvest index was recorded in the treatment halauxifen-methyl ester + florasulam at 10.20 g/ha (44.99%) *fb* halauxifen-methyl ester + florasulam at 7.6 g/ha *fb* halauxifen-methyl ester + florasulam at 12.70 g/ha. However, maximum harvest index was recorded under hand weeding treatment among all the weed control treatments [56].

Table 4. Influence of different herbicidal treatments on growth parameters, yield attributes and grain yield in wheat

Treatments	Plant height (cm)	Number of tillers/m ²	Grains/ear head	Grain yield (t/ha)	Harvest index (%)
	60 DAS	60 DAS			
T ₁ - Halauxifen methyl ester + florasulam at 7.6 g/ha	66.07	380.27	42.00	5.28	44.78
T ₂ - Halauxifen-methyl ester + florasulam at 10.20 g/ha	66.47	415.47	51.17	5.81	44.99
T ₃ - Halauxifen-methyl ester + florasulam at 12.70 g/ha	66.00	354.13	49.25	5.74	44.69
T ₄ - Halauxifen-methyl ester + florasulam at 25.50 g/ha	65.67	386.13	47.74	5.69	44.00
T ₅ - Mesosulfuron + Iodosulfuron at 14.40 g/ha	65.87	394.00	42.00	4.81	42.76
T ₆ - Sulfosulfuron + metsulfuron methyl at 32.0 g/ha	65.53	402.53	46.20	5.33	43.80
T ₇ - Metsulfuron + clodinafoppropargyl at 10.0 g/ha	65.27	382.93	45.56	5.07	43.33
T ₈ - Metsulfuron- methyl at 4.0 g/ha	63.33	395.87	44.75	4.86	43.18

T ₉ - Hand weeding 30 DAS	67.13	429.07	52.27	5.90	45.00
T ₁₀ - Weedy check	55.73	355.87	38.25	3.01	40.13
SEm±	1.65	0.04	0.02	0.03	-
CD at 5 %	4.78	0.13	0.06	0.09	-

4. CONCLUSION

It can be concluded that, the density and diversity of weeds was significantly altered by different weed management practices and these practices successfully reduced the density of dominated weeds. Highest magnitude of suppression was recorded with the post emergence application of halauxifen-methyl ester + florasulam at 10.20 g/ha and it was the best combination for effective control of grasses and broad leaved weeds which leads to maximum grain yield in wheat crop.

REFERENCES

1. Yadav, P. K., Sikarwar, R. S., Verma, B., Tiwari, S., & Shrivastava, D. K. (2023). Genetic Divergence for Grain Yield and Its Components in Bread Wheat (*Triticum aestivum* L.): Experimental Investigation. *International Journal of Environment and Climate Change*, 13(5), 340-348.
2. SINGH, H., JHA, G., RAWAT, A., BABU, S., & JHA, A. K. (2013). Low seed rate at surface sowing enhance resilience of physiological parameters and economics of wheat (*Triticum aestivum*). *The Indian Journal of Agricultural Sciences*, 83(8).
3. Tanisha Nirala, A.K. Jha, Badal Verma, Pushpendra Singh Yadav, Mahendra Anjna and Lakhna Bhalse. Bio efficacy of Pinoxaden on Weed Flora and Yield of Wheat (*Triticum aestivum* L.). *Biological Forum – An International Journal*. 2022; 14(4): 558-561.
4. Sisodiya Jitendra, Sharma PB, Verma Badal, Porwal Muskan, Anjna Mahendra, Yadav Rahul. Influence of irrigation scheduling on productivity of wheat + mustard intercropping system. *Biological Forum – An International Journal*. 2022;14(4):244-247.
5. IIWBR. 2020. Indian Institute of Wheat and Barley Research: <https://iiwbr.icar.gov.in/director-desk/>
6. Porwal, M., & Verma, B. (2023). Agronomic Interventions for the Mitigation of Climate Change, *Emrg. Trnd. Clim. Chng.* 2(1), 27-39. doi: <http://dx.doi.org/10.18782/2583-4770.122>
7. Verma, B., Porwal, M., Agrawal, K. K., Behera, K., Vyshnavi, R. G., & Nagar, A. K. (2023). Addressing Challenges of Indian Agriculture with Climate Smart Agriculture Practices, *Emrg. Trnd. Clim. Chng.* 2(1), 11-26. doi: <http://dx.doi.org/10.18782/2583-4770.121>
8. Pandey AK, KA Gopinath, Gupta Hari. Evaluation of sulfosulfuron and metribuzin for weed control in irrigated wheat (*Triticum aestivum*). *Indian Journal of Agronomy*. 2006; 51(2): 135-138.
9. Kantwa SR, Agrawal RK, Jha A, Pathan SH, Patil SD, Choudhary M. Effect of different herbicides on weed control efficiency, fodder and seed yields of berseem (*Trifolium alexandrinum* L.) in central India. *Range Management and Agroforestry*. 2019; 40(2): 323-328.
10. Verma B, Bhan M, Jha AK, Singh V, Patel R, Sahu MP, Kumar V. Weed management in direct-seeded rice through herbicidal mixtures under diverse agroecosystems. *AMA, Agricultural Mechanization in Asia, Africa and Latin America*. 2022;53(4):7299- 7306.
11. Yadav, P. S., Jha, A. K., Pachauri, V., Verma, B., Shrivastava, A., Chouhan, M., & Rajpoot, A. (2023). Oat genotypes response to different nitrogen levels under agro-climatic condition of Kymore Plateau zone of Madhya Pradesh.
12. Sahu, M. P., Kewat, M. L., Jha, A. K., Sondhia, S., Choudhary, V. K., Jain, N., ... & Verma, B. Weed prevalence, root nodulation and chickpea productivity influenced by weed management and crop residue mulch. *AMA, Agricultural Mechanization in Asia, Africa and Latin America*. 2022;53(6):8511-8521.

13. Shiv Swati, Agrawal S.B., Verma Badal, Yadav Pushpendra Singh, Singh Richa, Porwal Muskan, Sisodiya Jirtendra and Patel Raghav. Weed dynamics and productivity of chickpea as affected by weed management practices. *Pollution Research*. 2023; 42 (2):21-24.
14. Raghuwanshi, M., Jha, A. K., Verma, B., Sahu, M. P., & Dubey, A. (2023). Assessing the Effect of Weed Management Practices on Weed Flora, Growth and Yield of Fodder Maize (*Zea mays* L.). *International Journal of Plant & Soil Science*, 35(11), 112-120.
15. Kosina P, Reynolds M, Dixon J, Joshi A. Stakeholder erception of wheat production constraints, capacity building needs, and research partnerships in developing countries. *Euphytica*. 2007; 157: 475-483.
16. Galon L, Basso FGM, Chechi L, Pilla TP, Santin CO, Maico Andre Michelon, Bagnara MAM, et al. Weed interference period and economic threshold level of ryegrass in wheat. *Bragantia*, Campinas. 2019; 78(3): 409-422.
17. Meena V, Kaushik MK, Meena SK, Bhimwal JP, Chouhan BS. Influence of pre and post-emergence herbicide application on weed growth and nutrient removal in wheat (*Triticum aestivum* L.). *Journal of Pharmacognosy and Phytochemistry*. 2017; 6(6): 2413-2418.
18. Abbas G, Ali MA, Abbas Z, Aslam M, Akram M. Impact of different herbicides on broadleaf weeds and yield of wheat. *Pak J Weed Sci Res*. 2009; 15: 1–10.
19. Pahade, S., Jha, A. K., Verma, B., Meshram, R. K., Toppo, O., & Shrivastava, A. (2023). Efficacy of Sulfentrazone 39.6% and Pendimethalin as a Pre Emergence Application against Weed Spectrum of Soybean (*Glycine max* L. Merrill). *International Journal of Plant & Soil Science*, 35(12), 51-58.
20. Yadav PS, Kewat ML, Jha AK, Hemalatha K, Verma B. Effect of sowing management and herbicides on the weed dynamics of berseem (*Trifolium alexandrinum*). *Pharma Innovation*. 2023; 12(2): 2845-2848.
21. Sairam, G., Jha, A. K., Verma, B., Porwal, M., Sahu, M. P., & Meshram, R. K. (2023). Effect of Pre and Post-emergence Herbicides on Weed Flora of Maize. *International Journal of Plant & Soil Science*, 35(11), 68-76.
22. Jha, A. K., Shrivastva, A., Raghuwansi, N. S., & Kantwa, S. R. (2014). Effect of weed control practices on fodder and seed productivity of Berseem in Kymore plateau and Satpura hill zone of Madhya Pradesh. *Range Management and Agroforestry*, 35(1), 61-65.
23. Sairam, G., Jha, A. K., Verma, B., Porwal, M., Dubey, A., & Meshram, R. K. (2023). Effect of Mesotrione 40% SC on Weed Growth, Yield and Economics of Maize (*Zea mays* L.). *International Journal of Environment and Climate Change*, 13(7), 608-616.
24. Moss S. Integrated weed management (IWM): why are farmers reluctant to adopt non-chemical alternatives to herbicides? *Pest Manag Sci*. 2019; 75: 1205–1211.
25. Kraehmer H, Laber B, Rosinger C, Schulz A. Herbicides as weed control agents: state of the art: I. Weed control research and safener technology: the path to modern agriculture. *Plant Physiol*. 2014; 166: 1119–1131.
26. Verma B, Bhan M, Jha AK, Khatoon S, Raghuwanshi M, Bhayal L, Sahu MP, Patel Rajendra, Singh Vikash. Weeds of direct- seeded rice influenced by herbicide mixture. *Pharma Innovation*. 2022;11(2):1080-1082.
27. Raghuwanshi, M., Jha, A. K., Verma, B., Yadav, P. S., & Shrivastava, A. (2023). Weed Dynamics of Fodder Maize as Influenced by Different Herbicides. *International Journal of Environment and Climate Change*, 13(7), 245-251.
28. Jha AK, Yadav PS, Shrivastava A, Upadhyay AK, Sekhawat LS, Verma B, Sahu MP. Effect of nutrient management practices on productivity of perennial grasses under high moisture condition. *AMA, Agricultural Mechanization in Asia, Africa and Latin America*. 2023; 54(3): 12283-12288.
29. Yadav DB, Punia SS, Chauhan BS. Management of herbicide resistant (*Phalaris minor*) in wheat by sequential or tank mix application of post-emergence herbicide in north-western Indo-Gang etic plains. *Crop Protection*. 2016; 89: 239-247.
30. Piper, C.S. 1967. *Soil and Plant analysis*. Inter science publisher Inc., New York.
31. Walkley, A., and Black, C. A. 1934. An examination of the degtjareff method for detemining the soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*. 37: 29-38.
32. Jackson, M. L. 1967. *Soil Chemical Analysis*, prentice Hall of India Pvt. Ltd., New Delhi, 205.
33. Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *USDA, Circ*. 939.
34. Chapman, H.D. and Partt, P.F. (1961) *Methods of Analysis of Soils, Plants and Waters*. University of California. Berkeley.

35. Black, C. A. and Evans, D. D. 1965. Method of soil analysis. American Soc Agron, Madison, Wisconsin, USA. 131-137
36. Sahu, V., Kewat, M. L., Verma, B., Singh, R., Jha, A. K., Sahu, M. P., & Porwal, M. Effect of carfentrazone-ethyl on weed flora, growth and productivity in wheat. The Pharma Innovation Journal 2023; 12(3): 3621-3624.
37. Patel, R., Jha, A. K., Verma, B., Porwal, M., Toppo, O., & Raghuwanshi, S. (2023). Performance of Pinoxaden Herbicide against Complex Weed Flora in Wheat (*Triticum aestivum* L.). International Journal of Environment and Climate Change, 13(7), 339-345.
38. Aslam M, Hussain M, Hussain G, Rashid A. Efficacy of different herbicides for weed control in wheat crop. Pakistan Journal of Weed Science. 2007; 13 (2): 1-7.
39. Kumar S, Malik RS, Yadav, Malik RK. Performance of cultivars and Sulfosulfuron against weed in wheat. Indian Journal of Weeds Science. 2007; 39 (2): 44-47.
40. Patel Raghav, Jha AK, Verma Badal, Kumbhare Rahul, Singh Richa. Bio- efficacy of pinoxaden as post-emergence herbicide against weeds in wheat crop. Pollution research. 2023;42(1):115-117.
41. Jarwar AD, Arain MA, Rajput LS. Chemical weed control and sowing methods on production potential of wheat. Indian Journal of Agronomy. 2005; 48(3): 192-195.
42. Muhammad Ashiq NM, Ahmad N. Comparative efficacy of different herbicides to control grassy weeds in wheat. Pak. J. Weed Sci. Res. 2006; 12(3):157-61.
43. Kumar Abhishek, Pandey Dinesh, Patel JR, Agrawal HP, Agrawal AP, Chaure NK, Ahmad Anjum, Hetram, Rawate Deepika, Mitasha M. Efficacy of herbicides against diverse weed flora of wheat (*Triticum aestivum* L.). The Pharma Innovation Journal. 2022; 11(10): 11-15.
44. Yadav DB, Punia SS, Yadav A, Singh S, Lai R. Pinoxaden, an alternate herbicide against little seed canary grass (*Phalaris minor*) in wheat. Indian Journal of Agronomy. 2009; 54(4): 433-437.
45. Singh S, Singh H, Malik RK, Narwal S. Performance of tank mixture of Chlorsulfuron and Dinitroaniline herbicides for the control of weeds in wheat. Indian Journal of Weed Science. 2005; 37 (1&2): 20-22.
46. Dhiman Mukherjee. Herbicide combinations effect on weeds and yield of wheat in North-Eastern plain. Indian Journal of Weed Science. 2020; 52(2): 116–122.
47. Mishra JS, Yaduraj NT. Bio efficacy of Suifosulfuron against weeds in wheat in vertisols. Indian Journal of Weed Science. 2005; 37(1&2): 23-25.
48. Nekhat AF, Dhaka AK, Singh Bhagat, Kumar Amit, Bhuker Axay. Influence of herbicides and their mixtures on growth, yield attributes productivity and economics of wheat. Journal of Pharmacognosy and Phytochemistry. 2020; 9(5): 258-262.
49. Sharma Rajbir, Pahuja SS, Balyan RS, Malik RK. Effect of Sulfonyl-urea herbicides applied alone and tank mixture with Metribuzin on weeds in wheat and their residual effect on succeeding crop of sorghum. Indian Journal of Weed Science. 2002; 38: 178-183.
50. Shivran AC, Sarita, Choudhary J, Bamboriya Jitendra Singh. Effect of Different Herbicides on Growth and Yield of Wheat (*Triticum aestivum* L.). Int.J.Curr.Microbiol.App.Sci. 2020; 9(4): 438-448.
51. Singh S, Yadav AK, Balyan RS. Evaluation of AEE 130060 and MKH 6561 for weed control in wheat. Indian Journal of Weed Science. 2008; 40 (3&4):201 -204.
52. Mukherjee S, Goon A, Ghosh B, Kundu A, Chakrabarti K, Roy S, Bhattacharyya A. Persistence behaviour of a mixed formulation (florasulam 10% + halauxifen methyl 10.4% WG) in wheat. Journal of Crop and Weed. 2014; 10(2):414-418.
53. Dhawan RS, Punia SS, Singh S, Yadav D, Malik RK. Productivity of wheat as affected by continuous use of new low dose herbicides for management of little seedcanary grass (*Phalaris minor*). Indian Journal of Agronomy. 2009; 54(1):58-62.
54. Chhokar RS, Sharma RK, Gill SC, Meena RP. Herbicides for broad-leaved weeds management in wheat. Indian Journal of Weed Science. 2015; 47(4): 353–361.
55. Mitra, B., Barman, R., & Mondal, T. Control of broad-leaved weeds in wheat under eastern sub-Himalayan plains. Indian Journal of Weed Science. 2019; 51(1): 27–31.
56. Shivran AC, Choudhary J, Sarita. Efficacy of herbicides on broad-leaved weed and yield of wheat (*Triticum aestivum* L.). International Journal of Chemical Studies. 2020; 8(2): 180-184.