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WHEAT PRODUCTIVITY, PROFITABILITY AND WEED INDICES AS INFLUENCED BY SORGHUM EXTRACT AND CLODINAFOP + METSULFURON

Devi Lal Kikraliya[1]*, U.N. Shukla[2], Ramesh[3], K.K. Bijarnia[4], Moola Ram[5] and Anuj Kumar[6]

[1]*Department of Agronomy, Swami Keshwanand Rajasthan Agricultural University, Bikaner - 334 006, Rajasthan (India)*
[2]*Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur - 208 002, Uttar Pradesh (India)*
[3]*Department of Plant Breeding and Genetics,* [5]*Department of Agronomy, Agriculture University, Jodhpur - 342 304, Rajasthan (India)*
[4]*Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar - 125 004, Haryana (India)*
[6]*Department of Agronomy, Agriculture University, Kota - 324 001, Rajasthan (India)*
*****e-mail: *devilalkikraliya1997@gmail.com*

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ABSTRACT

Wheat is a staple food crop and cultivated in most part of the world with having diverse use in food and bakery industry. Its cultivation and production are much affected by various weed flora. Considering the losses caused by weeds, an ecological plus herbicidal approach was followed with the objective to enhance the productivity and profitability of wheat crop. Sorghum extract (1:3) *fb* ready-mix of clodinafop + metsulfuron 64 g ha^{-1} significantly increased the productivity by 37.55 kg ha^{-1} day^{-1} and profitability by ₹. 721.53 ha^{-1} day^{-1}. Further, it significantly reduced weed infestation over weedy check. It was concluded that integrated management of weeds in wheat through sorghum extract (1:3) + ready-mix of clodinafop + metsulfuron 64 g ha^{-1} yielded maximum productivity and profitability while minimizing the weed density, and improved weed indices.

Keywords: Herbicide, productivity, profitability, sorghum extract, wheat, weed

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the largest growing crop among the cereals in the world and offers 20% of the world's food resources (Patil *et al*., 2023). In India, wheat holds 2nd position with respect to the area and production, but stands 1st in productivity among all the cereals. Worldwide, India is among the top 10 producers of wheat with a total production of 113.29 m t from an area of 31.83 million ha and productivity of 3559 kg ha^{-1} (DES, 2023-24). Rajasthan, Maharashtra, Uttar Pradesh, Madhya Pradesh, Punjab, Haryana and Gujarat are top wheat growing states in India. In Rajasthan wheat is cultivated 2.79 million ha area with a production of 10.64 m t and productivity of 3807 kg ha^{-1} (Commissionerate of Agriculture, 2022-23). However, its production is affected by diseases and pests, including weed manifestation. More than one-third yield decrease in wheat is attributed to weeds as compared to the other pests (Mesterhazy *et al*., 2020). Weeds reduce wheat production by 10-43% by competing for nutrients, moisture and light, depending upon the management practices followed (Siyar *et al*., 2019; Vivek *et al*., 2019; Goudar, 2020). The production and quality of wheat mostly depend on the favourable environmental conditions and the agronomic practices especially weed management. Weed management practices play vital role in achieving maximum production of wheat.

Nature of crops, soil fertility and productivity affected by weed density and diversity (Ishaq *et al*., 2017). As compared to the crop, weeds absorb more nutrients so greatly impact the growth and yield of crop (Adnan *et al*., 2020). Therefore, it is imperative to have weed-free environment in wheat cultivation which can be achieved through herbicide-based weed management practices (Khaliq *et al*., 2014). Weed control through chemical means alone is not enough to suppress the weeds below the threshold level. However, cultural, mechanical, biological and integrated methods are also available to control the weeds and reduce crop competitiveness. Among those, the integration of herbicide and non-chemical (plant extracts) methods has become a suitable viable strategy for weed management in wheat. The secondary metabolites released by many plant species play a major role in weed management through allelopathic effect (Soliman *et al*., 2017). Allelopathy is a natural phenomenon in which different organisms negatively or positively influence the functioning of other organisms residing in their vicinity by secreting secondary metabolites (Huang *et al*., 2021). Allelochemicals positively impact the crop growth and negatively on weeds (Farooq *et al*., 2018; Rashid *et al*., 2018). Allelochemicals, applied at low concentration, are ecofriendly and do not affect the surrounding environment. Sorghum (*Sorghum bicolor*) water extract spray reduced weed biomass by 35-40% and increased wheat yield by 10-21% (Cheema and Khaliq, 2000). The increasing labour and fuel costs in many situations and inefficient weed management options have forced researchers to develop a suitable integrated weed management approach that would be economic and efficient approach. Therefore, this study was aimed to assess the influence of sorghum extract and ready-mix formulation of clodinafop + metsulfuron herbicide on wheat productivity, profitability, weed management indices, nutrient content, and their removal by weed.

MATERIALS AND METHODS

A field trial was conducted during *rabi* season 2021-22 at Instructional Farm, College of Agriculture, Jodhpur (Rajasthan) India. The average daily maximum and minimum temperature varied between 16.1 to 34.0ºC and 10.9 to 26.3ºC, respectively during experimentation period. A rainfall of 19.90 mm was received during crop growth period mostly in the last week of December to the first week of January. During experimental period, the mean daily relative humidity fluctuated between 27.1 to 88.1%. The soil of experimental field was sand-loamy in texture, slightly alkaline (pH 8.2) in soil reaction, non-saline in conductivity (EC 0.12 d Sm^{-1}), low in organic carbon (0.14%) and available nitrogen (177 kg ha^{-1}), medium in available phosphorus (22 kg ha^{-1}) and high in available potassium (330 kg ha^{-1}) contents. The soil bulk density was 1.77 Mg m^{-3} and field capacity 13.21%. The soil had a medium range of EC and pH that are congenial for better growth and development of crop.

The field experiment comprised of eleven treatment combinations: W_1: sorghum (*Sorghum bicolor*) extract (1:1) (sorghum extract: water), W_2: sorghum extract (1:2), W_3: sorghum extract (1:3), W_4: sorghum extract (1:4), W_5: ready mix of clodinafop + metsulfuron 64 g ha^{-1}, W_6: sorghum extract (1:1) + ready-mix of clodinafop + metsulfuron 64 g ha^{-1}, W_7: sorghum extract (1:2) + ready-mix of clodinafop + metsulfuron 64 g ha^{-1}, W_8: sorghum extract (1:3) + ready-mix of clodinafop + metsulfuron 64 g ha^{-1}, W_9: sorghum extract (1:4) + ready-mix of clodinafop + metsulfuron 64 g ha^{-1}, including two checks *i.e*. W_{10}: weed free, and W_{11}: weedy check. The trade name of clodinafop + metsulfuron is Vesta and is basically scetolactate synthase and acetyl CoA carboxylase inhibitor. The ready mix of clodinafop-propargyl 15 % WP + metsulfuron methyl 1% WP + 84% adjuvant was used in the experimentation. It. The experiment was conducted in a randomized block design (RBD) with each treatment replicated three times. The sorghum (*Sorghum bicolor*) plants were cut above ground and dried under the shade. The dried sorghum plants were cut into 2 to 3 cm pieces for extraction. Sorghum stovers were soaked in tape water in 1:10 ratio (weight: volume) and kept as such for 24 h for release of maximum amount of allelochemicals. After 24 h, the extract was filtered through a sieve and boiled to reduce the filtrate volume by 95%. As per treatment *viz.*, 1:1, 1:2, 1:3 and 1:4 (sorghum extract: water ratio) dilutions were sprayed 21 days after wheat sowing as per treatment. The ready-mix formulation of clodinafop + metsulfuron @ 64 g ha^{-1} were applied 30 days after sowing as per the treatments with the help of knapsack sprayer using 400 L water. The seeds were sown @ 100 kg ha^{-1} on 16 November 2021 by *pora* method at row spacing of 22.5 cm at 3-4 cm depth. The gross and net plot size was 7.0 m × 2.25 m and 6.0 m × 1.80 m, respectively. The recommended dose of fertilizer (90 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}) was supplied in the form of urea and diammonium phosphate (DAP). Half nitrogen and full dose of phosphorus were applied as basal dose at sowing time. Remaining nitrogen was applied as top dressing in standing crop through urea at first irrigation. Besides pre-sowing irrigation, five irrigations were given to the crop at critical stages *viz.* crown root initiation, tillering, late jointing, flowering and milking stage. Chloropyriphos 20 EC was applied at second irrigation to protect the crop from termite attack. The crop was harvested on 16 March 2022.

Weed control index (WCI)

Weed control index was assessed on 30, 60, 90 DAS and at harvest taking into consideration the reduction in weed population in the treated plot over the weedy check plot and expressed in percent. This formula used was as follows (Mani *et al*., 1973):

$$\mathrm{WCI} = \frac{\mathrm{WP_C} - \mathrm{WP_T}}{\mathrm{WP_C}} \times 100$$

Where $\mathrm{WP_C}$ = Weed population in weedy check/control plots; $\mathrm{WP_T}$ = Weed population in treated plot.

Weed persistence index (WPI)

Weed persistence index has enough relevance in studying the aspect of weed management on comparative basis and was assessed at 30, 60, 90 DAS and at harvest as per the formula of Mishra and Misra (1997):

$$\mathrm{WPI} = \left(\frac{\text{Weed population in control plot}}{\text{Weed population in treated plot}}\right) \times \left(\frac{\text{Weed dry weight in treated plot}}{\text{Weed dry weight in control plot}}\right)$$

Crop resistance index (CRI)

Crop resistance index indicates the relationship between a proportionate increase in crop biomass and a proportionate decrease in weed biomass in the treated plot and was assessed at 30, 60, 90 DAS and at harvest by using the equation of Mishra and Misra (1997):

$$\mathrm{CRI} = \left(\frac{\text{Crop dry weight in treated plot}}{\text{Crop dry weight in control plot}}\right) \times \left(\frac{\text{Weed dry weight in control plot}}{\text{Weed dry weight in treated plot}}\right)$$

Weed management index (WMI)

WMI is the ratio of yield increase over control due to the weed management and percent control of weed by the respective treatment, computed using the following formula (Mishra and Misra 1997; (Devasenapathy *et al*., 2008):

$$\mathrm{WMI} = \frac{\text{Per cent yield increase over control}}{\text{Per cent control of weeds}}$$

Agronomic management index (AMI)

The AMI was calculated as per formula of Mishra and Misra (1997).

$$\mathrm{AMI} = \left(\frac{(\text{Per cent crop yield over control}) - (\text{Per cent control of weeds})}{\text{Per cent control of weeds}}\right)$$

Integrated weed management index (IWMI)

The IWMI was calculated by the formula given by Mishra and Misra (1997).

$$\mathrm{IWMI} = \frac{(\mathrm{WMI} + \mathrm{AMI})}{2}$$

Where, WMI = Weed management index; AMI = Agronomic management index

Nutrient content and their removal by weeds

Representative weed samples were taken from each plot at 60 DAS and at harvest and shade dried. The samples were processed and subjected to chemical analysis for their nitrogen content by Kjeldahl's method (Piper, 1966), phosphorus by vanadomolybdo-phosphoric acid yellow colour method (Jackson, 1958) and potassium by flame photometer method (Bhargava and Raghupathi, 1993). The depletion of nutrients by weeds was estimated as per the following formula:

$$\text{Nutrient depletion (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in weeds (\%)} \times \text{Weed dry matter (kg ha}^{-1}\text{)}}{100}$$

Crop productivity and profitability

Crop productivity and profitability was calculated on the basis of increase in yield and profit day^{-1} ha^{-1}. This was calculated by using the following formula:

$$\text{Crop productivity (kg ha}^{-1}\text{ day}^{-1}\text{)} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Duration of crop (day)}}$$

$$\text{Crop profitability (₹. ha}^{-1}\text{ day}^{-1}\text{)} = \frac{\text{Net return (₹. ha}^{-1}\text{)}}{\text{Duration of crop (day)}}$$

Statistical analysis

The data was statistically analysed in accordance with the 'analysis of variance' technique (Panse and Sukhatme, 1985). The critical difference (CD) for the treatment comparisons was worked out where ever the variance ratio (F test) was found significant at 5% level of probability.

RESULTS AND DISCUSSION

Weed control index and weed persistence index

The maximum weed control index was recorded with the application of sorghum extract (1:3) at 21 DAS *fb* ready-mix of clodinafop + metsulfuron at 30 DAS, followed by treatment sorghum extract (1:2) application at 21 DAS *fb* ready-mix of clodinafop + metsulfuron at 30 DAS at all growth stages of the crop over other treatments (Table 1). This weed control might be due to a reduction in initial weed flora by use of sorghum extracts and later flushes of weeds died due to the counter-attack of ready-mix herbicide. Similar results were reported by Kumar *et al*. (2012), Naeem *et al.* (2018) and Singh *et al*. (2019) in wheat. Minimum weed persistence index was observed in sorghum extract (1:1) treatment and it was closely followed by sorghum extract (1:4) treatment at all the growth stages (Table 1). The weed persistence index was lower in all the sorghum extract treatments as compared to the weedy check because they suppress the weed growth. Similar trends were also recorded by Desmukh *et al*. (2020).

Crop resistance index CRI) and weed management index (WMI)

Maximum CRI was brought up by post-emergence and sequential application of sorghum extract (1:3) + ready-mix of clodinafop + metsulfuron, followed by treatment sorghum extract (1:2) + ready-mix of clodinafop + metsulfuron at all growth stages of crop, due to the less harmful effect of herbicide and sorghum extract as compared to other treatments. Weedy check had lowest CRI value (1.0) revealing the highest harmful effect on crop. The ready-mix formulations of clod. + met 64 g ha^{-1} provided CRI of 1.19, 3.28, 3.66 and 4.62% at all growth stages as compared to the weedy check (Table 2). Similar observations were reported by Yadav *et al*. (2022). Maximum WMI (14.35 and 0.46) at 30 and 60 DAS was observed in ready mix of clod. + met. 64 g ha^{-1}. The maximum WMI of 0.37 and 0.36% was observed at 90 DAS and at harvest stages, respectively, in treatment sorghum extract (1:3) + ready-mix of clodinafop + metsulfuron (Table 2).

Table 1: Weed control index (WCI), weed persistence index (WPI), grain and straw yield of wheat as influenced by sorghum extract (SE) and herbicide Ready mix of clodinafop + metsulfuron 64 g ha^{-1} (RMCM)

Treatments	WCI				WPI				Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest		
SE (1:1)	9.58	31.71	46.98	60.13	0.82	0.56	0.63	0.76	3392	4243
SE (1:2)	24.18	51.00	64.84	73.35	0.65	0.65	0.76	0.90	3815	4632
SE (1:3)	28.18	57.25	68.70	77.58	0.45	0.70	0.74	0.96	3933	4754
SE (1:4)	20.00	38.71	53.38	63.36	0.77	0.56	0.66	0.77	3584	4397
RMCM	1.87	44.88	58.92	66.86	0.92	0.60	0.69	0.75	3726	4544
SE (1:1) + RMCM	9.79	64.04	74.38	81.80	0.77	0.71	0.85	1.04	3999	4823
SE (1:2) + RMCM	25.03	79.94	87.28	90.77	0.55	0.99	1.33	1.42	4217	4918
SE (1:3) + RMCM	29.00	88.71	94.10	96.58	0.41	1.38	2.07	3.01	4543	5103
SE (1:4) + RMCM	18.75	71.05	79.25	85.01	0.64	0.86	0.97	1.16	4116	4913
Weed free	100.00	100.00	100.00	100.00	0.00	0.00	0.00	0.00	4850	5265
Weedy check	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	2959	4096
SEm±	1.68	0.84	0.73	0.67	0.06	0.06	0.09	0.08	36.42	50.75
$CD_{0.05}$	4.95	2.49	2.16	1.99	0.16	0.18	0.25	0.22	107.43	149.72

Agronomic management index (AMI) and integrated weed management index (IWMI)

Maximum AMI and IWMI values of 33.88 and 17.12%, respectively, were observed in sorghum extract (1:3) application + ready-mix of clodinafop + metsulfuron 64 g ha^{-1}, treatment, followed by sorghum extract (1:2) spray + ready-mix of clodinafop + metsulfuron 64 g ha^{-1} treatment (Table 2). Similar results were reported by Singh *et al*. (2019) and Kumar *et al*. (2012) in their studies on weed management in wheat. AMI and IWMI were maximum in all the sorghum extract and herbicidal treatments as compared to the weedy check as they suppressed the weed growth and created favourable conditions for crop growth which ultimately enhanced wheat grain yield.

Table 2: Crop resistance index (CRI), weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) in wheat as influenced by sorghum extract (SE) and herbicide ready-mix of clodinafop + metsulfuron (RMCM)

Treatments	CRI				WMI				AMI at harvest	IWMI at harvest
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest		
SE (1:1)	1.44	2.68	3.04	3.46	1.34	0.40	0.27	0.21	11.80	6.01
SE (1:2)	2.18	3.48	3.94	4.85	0.93	0.44	0.35	0.31	21.44	10.87
SE (1:3)	3.38	3.76	4.56	5.59	0.88	0.43	0.36	0.32	23.77	12.05
SE (1:4)	1.74	3.04	3.33	3.93	0.88	0.45	0.33	0.28	16.47	8.37
RMCM	1.19	3.28	3.66	4.62	14.35	0.46	0.35	0.31	19.58	9.95
SE (1:1) + RMCM	1.58	4.49	4.90	6.50	2.65	0.41	0.35	0.32	24.99	12.65
SE (1:2) + RMCM	2.67	6.15	6.56	9.61	1.20	0.37	0.34	0.33	28.83	14.58
SE (1:3) + RMCM	3.83	8.01	9.43	13.10	1.27	0.39	0.37	0.36	33.88	17.12
SE (1:4) + RMCM	2.40	4.74	5.46	7.18	1.50	0.40	0.36	0.33	27.09	13.71
Weed free	0.00	0.00	0.00	0.00	0.39	0.39	0.39	0.39	37.99	19.19
Weedy check	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
SEm±	0.24	0.15	0.08	0.09	1.96	0.01	0.01	0.02	0.72	0.36
$CD_{0.05}$	0.71	0.44	0.25	0.27	5.77	0.04	0.04	0.05	2.12	1.07

Nutrient contents and their removal by weeds

The post-emergence and sequential application of sorghum extract (1:3) + ready-mix of clodinafop + metsulfuron treatment gave maximum NPK content in wheat crop, and caused significantly lesser nutrient removal by weeds at all crop stages, followed by sorghum extract (1:2) + ready-mix of clodinafop + metsulfuron treatment as compared to the other treatments (Table 3; Fig. 1). These findings are in conformity with Ahmed *et al.* (2018) and Afzal *et al.* (2020). The integrated use of sorghum extract and ready-mix herbicide due to the combined action appears to have minimized the weed flushes, resulting in lesser dry matter accumulation vis-a-vis less NPK removal by weeds (Pandey *et al*., 2007; Kumar *et al*., 2012).

Table 3: Nitrogen and phosphorus contents and their removal by weeds, crop productivity and profitability in wheat as influenced by sorghum extract (SE) and herbicide Ready mix of clodinafop + metsulfuron 64 g ha^{-1} (RMCM)

Treatments	Nitrogen content (%)		Nitrogen removal (kg ha^{-1})		Phosphorus content (%)		Phosphorus removal (kg ha^{-1})		Productivity (kg ha^{-1} day^{1})	Profitability (₹. ha^{-1} day^{1})
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest		
SE (1:1)	1.130	1.260	2.40	4.56	0.280	0.380	0.59	1.38	28.04	490.04
SE (1:2)	1.220	1.320	2.14	3.78	0.370	0.473	0.65	1.36	31.53	583.92
SE (1:3)	1.243	1.343	2.06	3.43	0.400	0.493	0.66	1.26	32.50	611.91
SE (1:4)	1.157	1.283	2.21	4.29	0.310	0.420	0.59	1.40	29.62	538.93
RMCM	1.187	1.300	2.16	3.82	0.340	0.447	0.62	1.31	30.79	572.74
SE (1:1) + RMCM	1.270	1.363	1.79	3.04	0.430	0.520	0.61	1.16	33.05	610.44
SE (1:2) + RMCM	1.310	1.400	1.41	2.19	0.490	0.570	0.53	0.89	34.85	656.35
SE (1:3) + RMCM	1.330	1.423	1.12	1.72	0.520	0.607	0.44	0.73	37.55	721.53
SE (1:4) + RMCM	1.290	1.380	1.76	2.85	0.460	0.540	0.63	1.12	34.01	643.96
Weed free	0.000	0.000	0.00	0.00	0.000	0.000	0.00	0.00	40.08	715.96
Weedy check	1.110	1.223	6.15	14.58	0.233	0.350	1.29	4.16	24.45	432.71
SEm±	0.003	0.002	0.04	0.06	0.003	0.008	0.02	0.07	0.30	12.94
$CD_{0.05}$	0.008	0.007	0.12	0.18	0.008	0.025	0.06	0.22	0.89	38.16

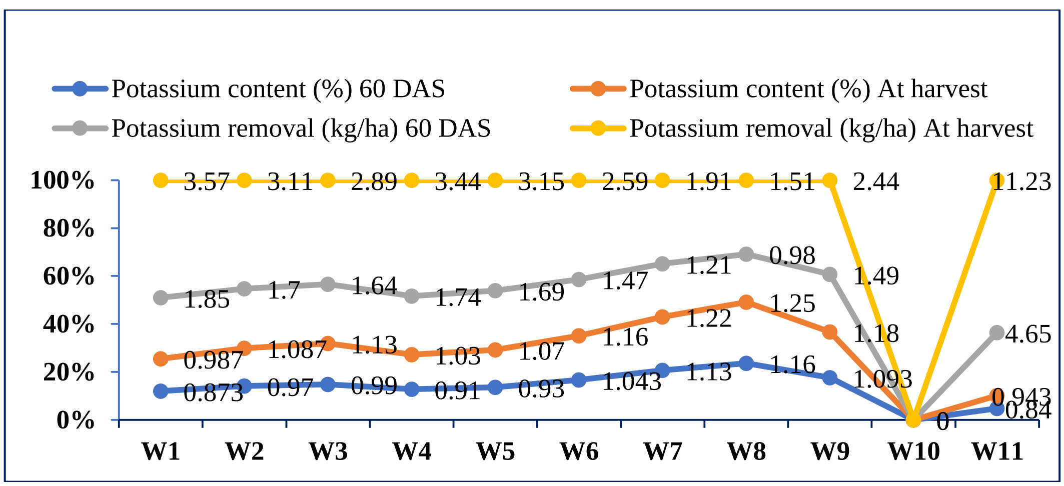

Fig. 1: Potassium content and their removal by weed as influenced by sorghum extract (SE) and herbicide ready mix of clodinafop + metsulfuron 64 g ha^{-1} (RMCM); W_1 - SE (1:1), W_2 - SE (1:2), W_3 - SE (1:3), W_4 - SE (1:4), W_5 - RMCM, W_6 - SE (1:1) + RMCM, W_7 - SE (1:2) + RMCM, W_8 - SE (1:3) + RMCM, W_9 - SE (1:4) + RMCM, W_{10} - Weed free, and W_{11} - Weedy check

Grain and straw yield

The treatment of sorghum extract (1:3) + ready-mix of clodinafop + metsulfuron gave significantly higher grain and straw yields (4543 and 5103 kg ha^{-1}, respectively) as compared to the other treatments, except weed free (Table 1). Sorghum extract (1:2) + ready-mix of clodinafop + metsulfuron treatment yielded 4217 kg grain ha^{-1}, which was at par with sorghum extract (1:4) + ready-mix of clodinafop +

metsulfuron treatment. Sorghum extract inhibits the physiological process particularly photosynthesis at PS-II in weed and clodinafop + metsulfuron kills grassy and broad leaved weeds, so help the wheat crop to acquire more nutrients from soil which translocate to the active site resulting in yield improvement (Naby and Ali, 2020).

Crop productivity and profitability

Among the weed control treatments evaluated sorghum extract (1:3) + ready-mix application of clodinafop + metsulfuron gave significantly higher crop productivity of 37.55 kg ha^{-1} day^{-1} and profitability of ₹**.** 721.53 ha^{-1} day^{-1} over weedy check, followed by treatment sorghum extract (1:2) + ready-mix application of clodinafop + metsulfuron. Both treatments were significantly superior over other treatments, except weed-free (Table 3). Maximum crop productivity of 40.08 kg ha^{-1} day^{-1} was observed in weed-free check. The application of sorghum extract (1:3) significantly increased the crop productivity (32.50 kg ha^{-1} day^{-1}) and profitability (₹**.** 611.91 ha^{-1} day^{-1}) as compared to other sorghum extract treatments. The increase in yield may be attributed to the minimum weed infestation and lesser crop-weed competition during the critical growth period (Bhutada and Bhale, 2014; Dubey *et al*., 2018).

Principal component analysis

The numerical score of each treatment on PC1 and PC2 shows how each treatment performed in terms of weed & crop management indices, nutrient content and their removal by weeds which is presented in Table 4. The PCA revealed that weed and crop management indices were most important factors separating the treatments (explained by PC1), with weed-free treatment (W_{10}**)** being the best performer (4.163), followed by sorghum extract (1:3) + ready-mix of clod. + met. (W_8) as moderate performer (2.604) and weedy check treatment (W_{11}) as poorest performer with PCA value -5.289 [Table 4, Fig 2]. Agronomic management index at harvest was positively correlated with weed persistence at 90 DAS and harvest stages, and weed control index at 90 DAS and harvest stages as acute angles was observed in these traits in sorghum extract (1:3) + ready-mix of clod. + met. treatment. The agronomic management index was negatively correlated with weed persistence at 30 DAS due to the highest obtuse angle (-5.289) in the treatment weedy check (W_{11}), [Table 4, Fig. 2]. Our results are in agreement with Loureiro *et al*. (2019).

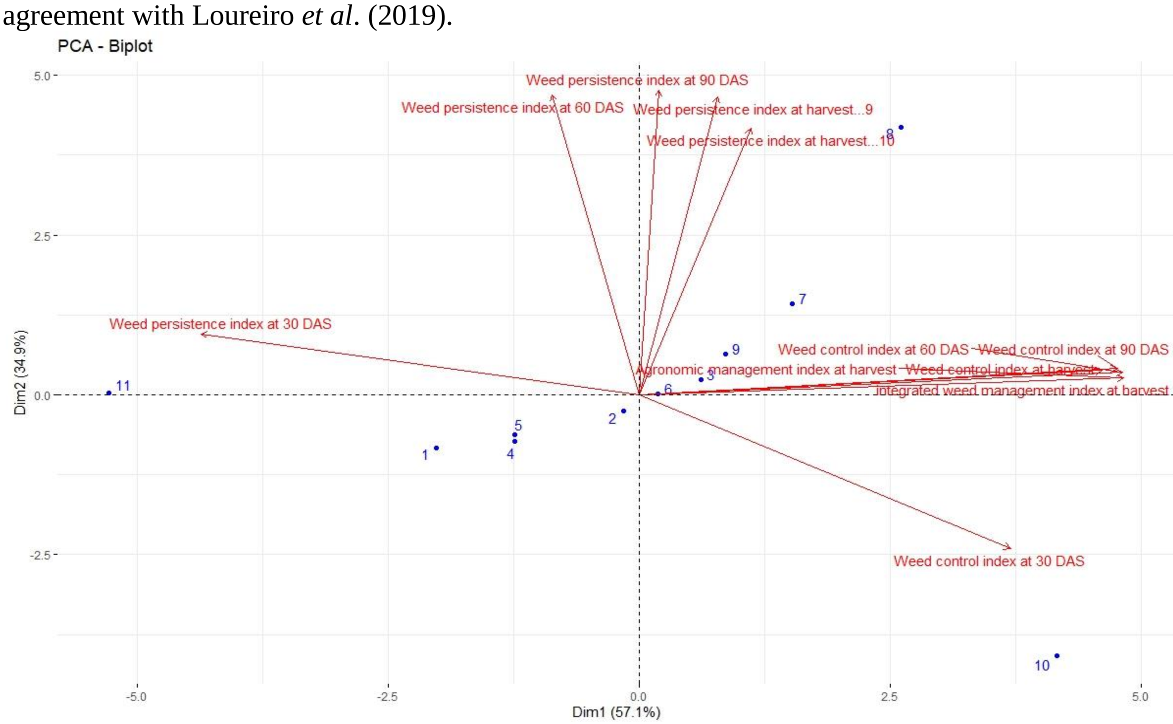

Fig. 2: Principal component analysis between weed management indices

Table 4: Principal component (PC) analysis of different treatments in wheat as influenced by sorghum extract (SE) and herbicide ready mix of clodinafop + metsulfuron 64 g ha^{-1} (RMCM)

Treatments	PC scores					
	D1		D2		D3	
	PC1	PC2	PC1	PC2	PC1	PC2
SE (1:1)	-2.026	-0.825	-1.658	-0.009	0.004	0.475
SE (1:2)	-0.156	-0.259	0.128	-0.350	-0.437	-0.380
SE (1:3)	0.610	0.234	0.593	-0.230	-0.514	-0.685
SE (1:4)	-1.241	-0.734	-0.609	-0.397	-0.119	0.124
RMCM	-1.241	-0.628	0.150	-0.916	-0.220	-0.188
SE (1:1) + RMCM	0.185	0.010	0.760	0.118	-0.468	-1.136
SE (1:2) + RMCM	1.527	1.422	1.726	1.131	-0.391	-1.974
SE (1:3) + RMCM	2.604	4.190	3.385	2.096	-0.246	-2.496
SE (1:4) + RMCM	0.863	0.642	1.174	0.274	-0.619	-1.371
Weed free	4.163	-4.085	0.199	-3.216	7.279	2.533
Weedy check	-5.289	0.033	-5.847	1.497	-4.268	5.097
Maximum	4.163	4.190	3.385	2.096	7.279	5.097
Minimum	-5.289	-4.085	-5.847	-3.216	-4.268	-2.496

D1: The numerical score of each treatment on principle component 1 and principle component 2 during PC analysis of different characters *viz*. weed control index and weed persistence index at 30, 60, 90 DAS and at harvest and agronomic management index and integrated weed management index at harvest.

D2: The numerical score of each treatment on principle component 1 and principle component 2 during PC analysis of different characters *viz*., crop resistance index at 60, 90 DAS and at harvest, weed management index at 30, 60, 90 DAS and at harvest, agronomic management index at harvest and profitability at harvest (₹. ha^{-1} day^{1}).

D3: The numerical score of each treatment on principle component 1 and principle component 2 during PC analysis of different characters *viz*., nitrogen, phosphorus and potassium content (%) in weed at 60 DAS and at harvest and nitrogen, phosphorus and potassium removal kg ha^{-1} by weed at 60 DAS and at harvest.

PC1 and PC2 are first and second principle components.

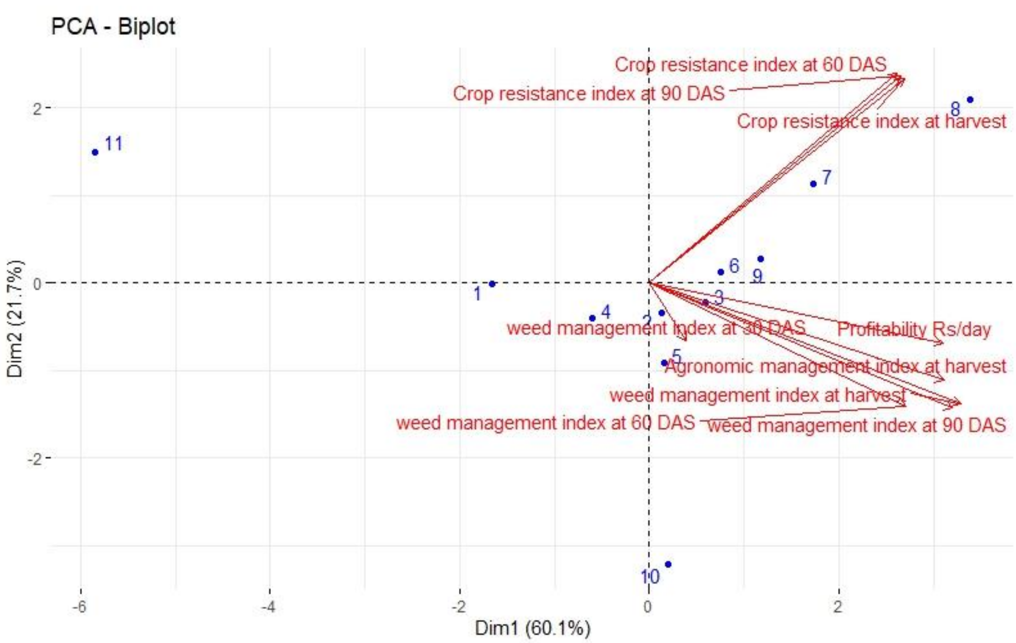

Fig. 3: Principal component analysis between crop and weed management indices

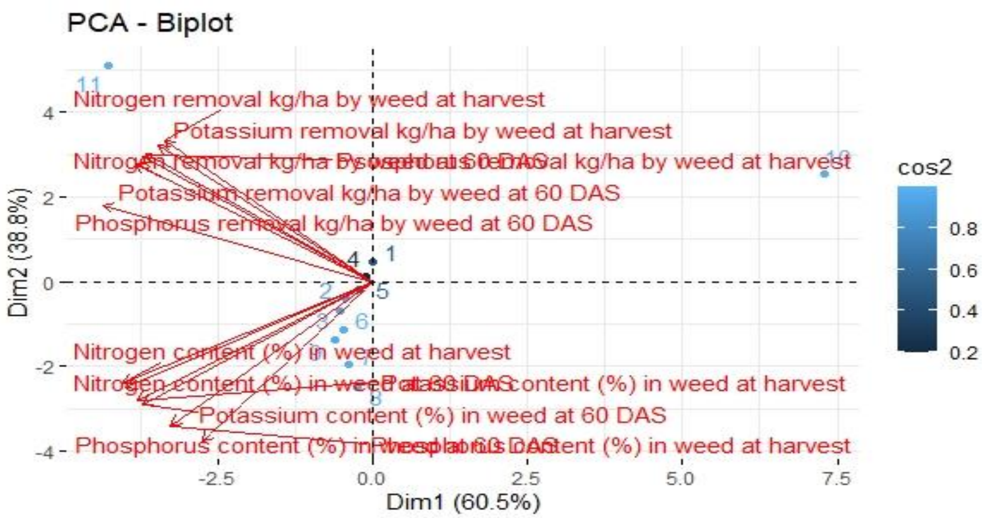

Fig. 4: Principal component analysis between nutrient content and their removal by weeds

Crop resistance index at 60, 90 DAS and at harvest was highest and positively correlated with weed management index at different stages and agronomic management index at harvest as acute angle was present in these traits under the treatment sprayed with sorghum extract (1:3) + ready-mix of clod. + met. (W_8) and sorghum extract (1:2) + ready-mix of clod. + met. (W_7) with PCA value of 3.385 and 1.726, respectively. Table 4 and Fig. 3 depict that PCA biplot in treatments is associated with weed and crop management indices. These results corroborate with Golzarian and Frick (2011).

Nitrogen, phosphorus and potassium content in weeds were negatively correlated with nitrogen, phosphorus, and potassium uptake by weed due to the highest obtuse angle present in these traits under treatment weedy check (W_{11}) with PCA value -4.268. Weed-free (W_{10}) and sorghum extract (1:1) was positively correlated between nutrient content and their removal by weed with PCA values 7.279 and 0.0004, respectively (Table 4; Fig. 4).

Regression studies

The wheat crop productivity was positively correlated with the profitability, with a correlation coefficient value of 0.9662. This was supported by the regression analysis as profitability increased by ₹. 20.075 ha^{-1} day^{-1} (Fig. 5). The weed control index, crop resistance index and agronomic management index were positively correlated with correlation co-efficient values of 0.8171, 0.1466 and 0.9763, respectively. This was validated by regression analysis wherein wheat crop productivity showed increase by 0.1434, 0.4488, and 0.4072 kg ha^{-1} day^{-1} in WCI, CRI, and AMI at harvest, respectively (Fig. 5-8).

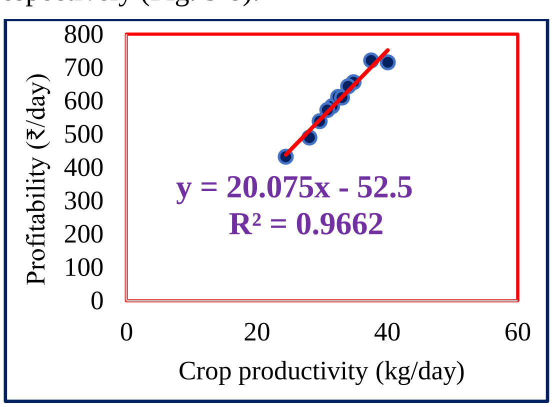

Fig. 5: Regression analysis between crop productivity and profitability

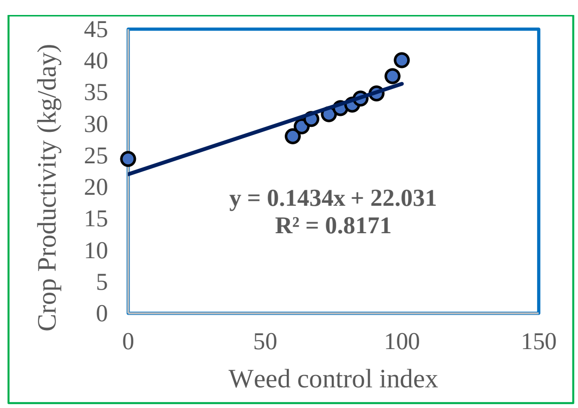

Fig. 6: Regression analysis between crop productivity and weed control index

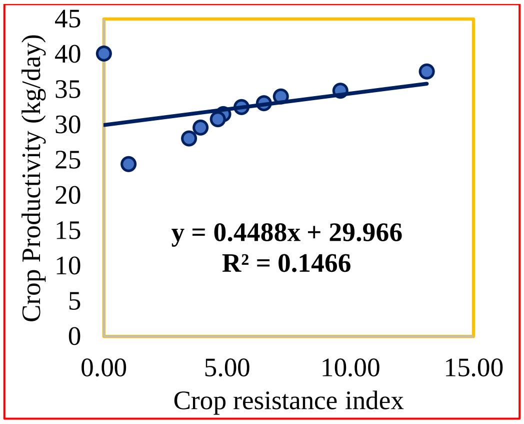

Fig. 7: Regression analysis between crop productivity and crop resistance index

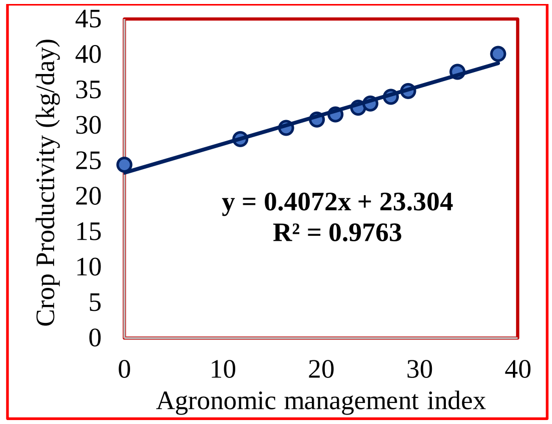

Fig 8: Regression analysis between crop productivity and agronomic management index

Conclusion: The sequential application of sorghum extract (1:3) *fb* ready-mix of clodinafop + metsulfuron 64 g ha^{-1} significantly reduced weed intensity, created favourable values of weed indices *i.e*. WCI, WPI, CRI, WMI, AMI and IWMI and resulted in higher crop productivity and profitability. This was followed by treatment sorghum extract (1:2) + ready-mix of clodinafop + metsulfuron 64 g ha^{-1}. The above findings are based on one-year experimentation which need to be validated through further experimentation to arrive at a specific recommendation.

Conflict of interest: The authors declare that they have no known competing personal relationships that could have appeared to influence the research work reported in this paper.

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