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RESEARCH ARTICLE

Integration of allelopathic water extracts with cultural practices for weed management in organic wheat

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ABSTRACT

Weed management is a major constraint in organic wheat production systems and integration of non-herbicidal weed management practices is the only available option. The present study was conducted at two locations during 2019-20 to evaluate the efficiency of allelopathic water extracts coupled with cultural practices in managing the weeds in organic wheat. The treatments consisted of two wheat varieties (tall and dwarf) and seven weed management treatments. The taller wheat variety PBW 677 had significantly lower weed biomass (21.4 to 28.2%) at harvest and higher grain yield (7.4 to 15.4%) than the dwarf variety Unnat PBW 550 and recorded better net returns and B:C at both the locations. Among the weed management treatments, hand weeding twice recorded maximum reduction in weed density (44.6 to 46.2%), and weed dry biomass (44.6% to 58.2%) at 75 days after sowing (DAS). The next best treatment in reducing weed density (38.9 to 45.3%) and dry biomass (41.1 to 46.5%) was line sowing of pre-germinated wheat seeds + wheel hoeing. This was followed by line sowing of pre-germinated wheat seeds + plant extract spray. The corresponding increases in wheat grain yields with above mentioned treatments at location I and II, compared to weedy check, were 69.6 and 66%; 42.7 and 51.8%, and 17.7 and 30.7%, respectively. Under labour constrained situations, line sowing of pre-germinated wheat seeds followed by wheel hoeing or application of mixed plant extract of sorghum, sunflower and raya at 18 L/ha each at 25 and 50 DAS of wheat can provide effective weed management, higher grain yield and better economic returns in organic wheat production.

Keywords: Allelopathy, Cultural management, Organic wheat, Plant extract, Weed management

Wheat (*Triticum aestivum* L.), a staple food of most of the people, is one of the three important cereals (rice, wheat, maize) of world having major contribution in global food security, hence considered as economic backbone of global food security. In India, it is the major cereal after rice and grown on an area of 31.12 million hectare with production of 109.58 million tonnes and an average productivity of 3.52 t/ha during 2020-21 (Anonymous 2022).

Organic food is gaining popularity due to its health benefits *eg.* higher antioxidants concentration, omega 3 fatty acids *etc.* (Vigar *et al.* 2020) as against food grown using conventional agricultural practices and wheat is no-exception. Organic food contains lower amount of pesticide residues compared to conventional food (Singh 2021). Among the pests, weeds are the most problematic in nature as weeds cause the highest loss in wheat productivity (Jabran 2015). The weed menace is more under organic wheat production as the herbicides' usage is prohibited (Singh 2021). The herbicides use in conventional farming was proved to lead to environmental, human and animal health problems as well as resistance development in weeds (Głąb *et al.* 2017). Alternatively, the effectiveness of cultural practices and allelopathic extracts in managing weeds was reported (Aulakh *et al.* 2017, Jabran 2015, Farooq *et al.* 2020).

Allelopathy is a natural phenomenon in which different plants or organisms release chemical compounds (*i.e.* secondary metabolites/ allelochemicals) which influence the function of other plants or organisms in their vicinity in a positive or negative way (Ashraf *et al.* 2017). Rye (*Secale cereale*), sorghum (*Sorghum bicolor*), rapeseed-mustard (*Brassica* spp.), sunflower (*Helianthus annuus*), tobacco (*Nicotiana* spp.) and wheat (*Triticum aestivum*) have been reported to release allelochemicals (Jabran *et al.* 2015). Weeds (*Fumaria indica*, *Phalaris minor*, *Rumex dentatus* and *Chenopodium album*) growth suppression in wheat crop with allelopathic plant water extract of sorghum was reported (Cheema *et al.* 2000). However, crop cultivars, developmental stages of crops, and environmental conditions affect concentration and

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phytotoxicity of allelochemicals (Weston *et al.* 2013). Arif *et al.* (2015) reported reduction in total weed density and biomass and increase in wheat yield with two foliar sprays of mixture of sorghum, sunflower and brassica extracts at the rate of 18 L/ha each at 25 and 40 days after sowing (DAS) of wheat. Awan *et al.* (2012) also reported decreased weed infestation and increased wheat yield when mixture of sorghum, sunflower and brassica extracts at the rate of 4 L/ha each was sprayed at 30 and 60 DAS. The highest weed reduction was observed when sorghum, sunflower and *brassica* were applied in combination which might be due to interaction among allelochemicals to enhance overall phytotoxicity (Glab *et al.* 2017).

In organic wheat production, cultural practices or agronomic manipulations are done to provide initial start-up to the crop so that crop can smother weeds or can compete more efficiently with weeds (Bond *et al.* 2001; Bhullar *et al.* 2017). Use of crop competition is considered as a cost effective method of weed suppression and enhancing crop yields, particularly in cereals and so this method can be employed for future weed management research (Ramesh *et al.* 2017, Meulen and Chauhan 2017). This study was aimed at evaluating the integrated effect of cultural and allelopathic weed management practices on suppression of weeds and performance of wheat under organic management.

MATERIALS AND METHODS

This field experiment was carried out during *Rabi* 2019-20 at two locations [location I –Punjab Agricultural University, Ludhiana (30°54' N latitude, 75°48' E longitude), and location II – Grewal Natural Farm, Dheri (30°92' N latitude, 75°88' E longitude)] in Punjab. The climate at both the locations is subtropical and semi-arid having hot and dry summer (April to June), hot humid monsoon period (July to September), mild winter (October to November) and cold winter (December to February). During summer, temperature generally goes above 39°C and numerous frosty spells are observed during winters (December and January) when minimum temperature reaches below 0.5°C. Annual average rainfall in Punjab is 650 mm, from which nearly 75% is received during monsoon period (July to September). The experimental soil at location I was sandy loam having pH 6.24, electrical conductivity 0.18 dS/m, organic carbon 0.78%, available nitrogen 226 kg/ha, available phosphorus 30 kg/ha and available potassium 223 kg/ha, and at location II, it was silty loam having pH 6.71, electrical conductivity 0.20 dS/m, organic carbon 0.49%, available nitrogen 188 kg/ha, available phosphorus 20.6 kg/ha and available potassium 239 kg/ha. The cropping systems were moong-wheat and basmati rice-wheat at location I and II, respectively.

The treatments were replicated thrice in a randomized complete block design with combination of two wheat varieties [PBW 677 (tall) and Unnat PBW 550 (dwarf)] and seven weed management treatments – weedy check, hand weeding twice at 30 and 60 DAS, plant extract spray (PE), pre-germinated wheat seeds + broadcast sowing (PGS + broadcast), pre-germinated wheat seeds + broadcast sowing + plant extract spray (PGS + broadcast + PE), pre-germinated wheat seeds + plant extract spray (PGS + PE), and pre-germinated wheat seeds + wheel hoeing at 17 and 55 DAS (PGS + wheel hoe). Sorghum, sunflower and raya plant extract used was tank mix of their allelopathic crop water extracts in 1:1:1 ratio at 18 L/ha each and was sprayed at 25 and 50 DAS of wheat using 375 L/ha water. The stovers of sorghum, sunflower and raya varieties (S-898, PSH 1962 and PBR 357, respectively) were used for preparing the allelopathic crop water extract. The stover was cut into 2-3 cm pieces and were soaked separately in tap water in ratio of 1:10 (stover: water). After 24 hours, extract was filtered and boiled to concentrate the filtrate to reduce the volume by 95% (Cheema and Khaliq 2000). The extracts were prepared afresh for each spraying. Wheel hoeing was done before first irrigation (17 DAS) and afterwards (55 DAS), when soil was at moisture condition workable with wheel hoe after rains.

Pre-germination of wheat seeds was done by soaking seeds in water for 10 hours. After soaking, the seeds were sprouted by spreading on gunny bags as a thin layer and covering them with wet gunny bags for 24 hours. The wheat seeds in all the treatments were smeared with *beejamrit* before sowing. *Beejamrit*, a seed treatment concoction in natural farming, was prepared by hanging five kg fresh cow dung, in a cloth bag, in 20 L of water. Fifty gram lime in a cloth bag was put in one litre water separately. After 14 hours, the cloth bag containing cow dung was squeezed and to this solution 5 L cow urine, 50 g virgin soil and lime water were added. Farmyard manure (FYM) at 12.5 t/ha was applied at the time of seedbed preparation in all the treatments. Wheat varieties Unnat PBW 550 and PBW 677 were sown at seed rates of 112.5 and 100 kg/ha (recommended seed rates in Punjab for the respective variety characters), respectively at row spacing of 20 cm or broadcast as per the treatments. The crop was sown on 9th and 15th November, 2019 at location I and II, respectively. The crop received only one irrigation at location I and no irrigation at location II due to well distributed rainfall throughout the crop growth period. The crop was sprayed two times with Neemkavach (Azadirachtin 0.15% EC) at 2.5 L/ha in 250 L water at ear head stage for control of aphid. The crop was harvested manually in last week of April, 2020 at both the locations.

Weed density was recorded by using 0.6 x 0.6m quadrat and weed control efficiency was computed by taking dry weed biomass recorded at 75 DAS. Effective tillers of wheat were recorded from three random places from 50 cm row length in line sown plots and from 0.6 x 0.6 m quadrat in broadcast sown plots and were converted to number/m^2. Weed density and dry biomass data were subjected to square root transformation for statistical analysis as per factorial randomized complete block design using CPCS1 software developed by the Department of Mathematics and Statistics, PAU, Ludhiana. The economic analysis was done by considering variables costs and B:C by using gross returns to cost of cultivation.

RESULTS AND DISCUSSION

Effect on weeds

Major weed species included *Rumex dentatus, Medicago denticulata, Phalaris minor* at both the locations, *Anagallis arvensis* at location I and *Solanum nigrum* at location II. *Rumex dentatus* and *Medicago denticulata* were relatively more dominant at location I whereas *Phalaris minor* was dominant at location II. Other weed species were *Chenopodium album* and *Lepidium sativum*.

Weed density did not differ significantly with wheat varieties at both the locations (**Table 1**). Hand weeding caused significantly lower weed density at both the locations, compared to all the other treatments except PGS + wheel hoe at 75 DAS (**Table 1**). The lower weed density in hand weeding and PGS + wheel hoe treatments might be due to the weeding at 60 DAS and wheel hoeing at 55 DAS, respectively. At location I, significantly higher weed density was recorded in weedy check than all the other treatments except PGS + broadcast and PGS + broadcast + PE which were statistically at par with weedy check indicating ineffectiveness of these treatments in managing the weeds. However, at location II, only PGS + broadcast, and PE were statistically at par with weedy check indicating their inefficiency. Hussain (2015) and Awan *et al* (2012) also reported hand weeding as the most effective method of reducing weed density. At harvest, the differences in weed density became non-significant at both the locations. This might be due to the completion of life cycle of majority of the weeds till harvest of the wheat crop.

Wheat variety PBW 677 had significantly lowered weed biomass than Unnat PBW 550 (28.2, 21.4 % at location I and II, respectively) due to greater plant height of PBW 677 which suppressed the weeds leading to less accumulation of dry matter by weeds (**Table 1**). Korres and Froud-Williams (2002) also reported that diverse weed flora was reduced by winter wheat cultivars having greater crop height as well as rapid tillering capability. Greater the height of crop genotype, the higher was the weed suppression (Chokkar *et al* 2012, Sandhu *et al* 1981).

Hand weeding significantly lowered weed biomass than all the other treatments at 75 DAS at both the locations and it was followed by PGS + wheel hoe which had also significantly lower weed biomass than rest of the treatments (**Table 1**). The lower weed biomass in hand weeding and PGS + wheel hoe might be due to reduced weed density (**Table 1**) as well as small-sized weeds as a result of weeding at 60 DAS and wheel hoeing at 55 DAS, respectively. The higher weed biomass in PGS + wheel hoe than hand weeding might be due to comparatively more intra-row weeds. Among rest of the treatments, PGS+PE had significantly lower weed biomass than all the other treatments except PE. This can be attributed to the adverse effect of the plant extract on dry matter accumulation by weeds. Suppression of growth of weeds with allelopathic crop water extracts has also been reported by Cheema *et al* (2000a). Awan *et al* (2012) reported that multiple weed flora in wheat was comparatively better controlled than weedy check with mixture of aqueous extracts of sorghum, sunflower and brassica. The highest weed biomass was recorded in weedy check and it was statistically at par with PGS + broadcast, and PGS + broadcast + PE. At location II, hand weeding had the lowest weed biomass which was statistically at par with PGS + wheel hoe. Weedy check had the highest weed biomass and was statistically at par with other treatments except hand weeding and PGS + wheel hoe. The variation among the two locations might be due to different soil types *i.e.* sandy loam and silty loam at location I and II respectively which led to less or more resistance to growth of weeds from soil e.g. in sandy loam soils, in broadcast fields, early growth of different weeds due to less resistance by soil took place which led to higher biomass at later stages. It might also be due to different type of weed dominance and soil fertility at both the locations. In plant extract treatments, the reduction in weed biomass might be due to synergistic effect of allelochemicals which adversely affect the physiological and metabolic processes of weeds due to their phytotoxicity to weeds when applied in combination. Phytotoxic activity exhibited by extracts of sunflower and sorghum could be due to the presence of allelochemicals such as sorgoleone, heliannnone and leptocarpin (Bogatek *et al*. 2006). It might be possible that extracts had interfered with cell division, hormone biosynthesis, mineral uptake, stomatal oscillations, photosynthesis, respiration, protein metabolism and plant water relations that caused a reduction in weeds (Arif *et al.* 2015).

At harvest, there were non-significant differences among weed management practices at location I. However, at location II, the weedy check had the highest weed biomass and it was statistically at par with all the other treatments except PGS+wheel hoe and hand weeding (**Table 1**). Lesser weed biomass in PGS+wheel hoe and hand weeding might be due to comparatively lower weed density and small size of weeds in these treatments.

Among the varieties, Unnat PBW 550 recorded higher weed control efficiency than PBW 677 at 75 DAS (**Figure 1**). However, the situation reversed at harvest with better weed control efficiency with PBW 677 due to significantly lower weed biomass in PBW 677 than Unnat PBW 550 (**Table 1**). Unnat PBW 550 recorded higher weed index than PBW 677 at both the locations (**Figure 1**).

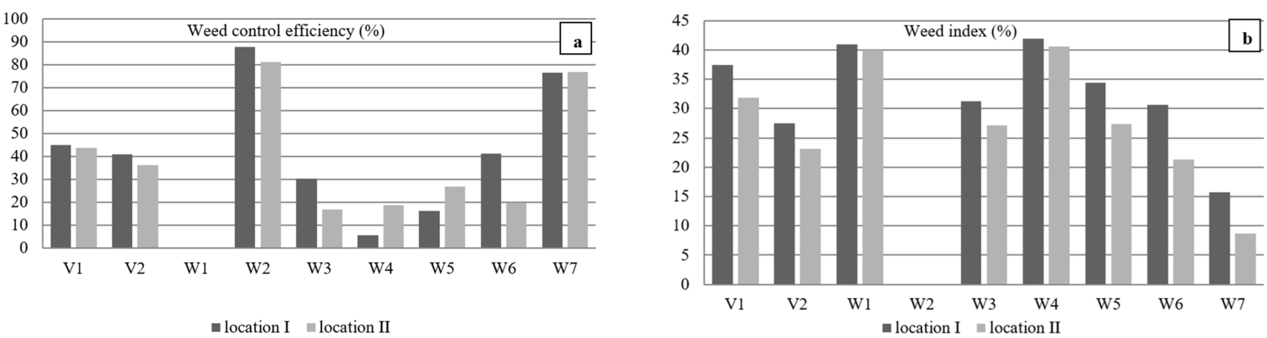
Higher weed index meant more yield loss which might have resulted due to more weed biomass at harvest of Unnat PBW 550 (**Table 1**) which adversely affected wheat grain yield (**Table 2**) of Unnat PBW 550.

Among the weed management practices, hand weeding had the highest weed control efficiency followed by PGS + wheel hoe at both the locations. At location I, PGS + wheel hoe was followed by PGS+PE, PE, PGS + broadcast + PE, PGS + broadcast. At location II, PGS + wheel hoe was followed by PGS + broadcast + PE, PGS + PE, PGS + broadcast and PE and weedy check. The lowest weed index was recorded in hand weeding followed by PGS + wheel hoe, PGS+PE, PE, PGS + broadcast + PE, weedy check and PGS + broadcast. Compared to location I, better weed control efficiency at 75 DAS at location II in PGS + broadcast and PGS + broadcast + PE might be due to better emergence in these treatments. However, weed index was the highest in PGS + broadcast due to negative effect of broadcasting as a sowing method.

Effect on crop

The wheat varieties did not differ significantly in respect of ear length, number of grains per ear and effective tillers (**Table 2**). However, the thousand grain weight was significantly higher in PBW 677 than Unnat PBW 550. This might be due to less competition of weeds (**Table 1**) and higher plant height in PBW 677 as compared to Unnat PBW 550 which might have led to more accumulation of photosynthates to grains in PBW 677.

Among the weed management treatments at location I, hand weeding had the highest number of grains per ear, which was at par with PGS + wheel hoe. Among rest of the treatments, PE and PGS+PE, at par with each other, had significantly higher number of grains per ear than weedy check. At location II, hand weeding had the highest number of



*V1= Unnat PBW 550, V2= PBW677, W1= Weedy check, W2= Hand weeding, W3= PE, W4= PGS + broadcast, W5= PGS + broadcast + PE, W6= PGS + PE, W7= PGS + wheel hoe, PGS = pre-germinated wheat seeds, PE = plant extract spray

Figure 1. Effect of various treatments on a) weed control efficiency, b) weed index

grains per ear which was statistically at par with all the other treatments except weedy check. Reduction in weeds results in more photosynthates assimilation in wheat and subsequently their translocation towards grains (Borras *et al.* 2004) which could be the reason behind higher number of grains per ear. Hand weeding had the highest number of effective tillers which was statistically at par with all the other treatments except weedy check and PGS + broadcast. Lesser number of effective tillers in weedy check and PGS + broadcast could be attributed to more weed competition in these treatments. Arif *et al* (2015), Hussain (2015), Awan *et al* (2012) also had similar findings. At location I, hand weeding twice recorded the highest thousand grain weight which was statistically at par with all the other treatments except weedy check. More weed competition in weedy check (**Table 1**) might have resulted in lower thousand grain weight. The lesser number of effective tillers in PGS + broadcast might have resulted in statistically similar thousand-grain weight with hand weeding. At location II, hand weeding recorded the highest thousand grain weight which was statistically at par with PGS + wheel hoe. This could be attributed to lesser weed competition (**Table 1**) than other treatments. Among rest of the treatments, weedy check had the lowest thousand grain weight which was statistically at par with all the other treatments.

Plant extract application on crop improved yield attributes could be attributed to its negative effect on weeds and positive effect on crop. The increment in wheat yield can be attributed to less competition to crop because of good weed control or due to hormesis (Abbas *et al* 2017) which is the stimulatory effect of toxicants due to low dose (Calabrese 2005).

The wheat variety PBW 677 recorded significantly higher grain yield (4.06 and 3.88 t/ha at location I and II, respectively) than Unnat PBW 550 (3.78 and 3.36 t/ha at location I and II, respectively) (**Table 2**). The increase being 7.4 and 15.5% at location I and II, respectively. This might be due to significant lower weed biomass accumulation in the former variety due to suppression of weeds because of more plant height (**Table 1**). The lesser weed competition in PBW 677 might have contributed to better growth and yield attributes in this variety. Higher the height of genotype of a crop, the higher is the weed suppression (Sandhu *et al* 1981) which might have led to significantly better yield in PBW 677 than Unnat PBW 550. Kumar *et al* (2007) also reported enhanced grain yield of wheat and higher weed suppression in wheat cultivars, PBW 343, WH 542 and HD 2687, which was due to higher plant height and smothering potential compared to other cultivars.

Among the weed management practices, hand weeding recorded significantly higher grain yield (5.44 and 4.73 t/ha at location I and II, respectively) than all the other treatments at both the locations. The corresponding yield increases with respect to weedy check were 69.5 and 66%. The highest grain yield in hand weeding might be due to better removal of weeds which resulted in minimum weed competition to crop and influenced yield attributes positively. Among rest of the treatments, PGS + wheel hoe had significantly higher grain yield (4.58 and 4.32 t/ha at location I and II, respectively) than all the other

Table 1. Effect of wheat varieties and weed management treatments on weed density and biomass

Treatment	Location I				Location II			
	Weed density (no./m^2)		Weed biomass (g/m^2)		Weed density (no./m^2)		Weed biomass (g/m^2)	
	75 DAS	At harvest	75 DAS	At harvest	75 DAS	At harvest	75 DAS	At harvest
Variety								
Unnat PBW 550	17.7(290)	10.0(84)	7.1(41.22)	5.8(26.22)	15.0(209)	13.9(173)	4.2(11.0)	10.7(102)
PBW 677	17.8(298)	9.5(76)	7.2(43.04)	4.5(14.42)	14.5(195)	13.0(149)	3.8(8.7)	8.8(63)
LSD (p=0.05)	NS	NS	NS	0.95	NS	NS	NS	0.97
Weed management								
Weedy check	21.3(412)	10.0(85)	9.1(66.71)	5.2(18.95)	18.5(308)	15.6(215)	4.8(15.1)	11.2(123)
Hand weeding	11.8(117)	9.7(77)	3.8(8.11)	3.8(8.28)	10.0(82)	12.5(141)	2.7(2.9)	8.7(61.5)
PE	19.2(332)	9.0(65)	7.8(46.40)	4.3(13.29)	16.3(236)	13.9(171)	4.5(12.4)	10.1(86.0)
PGS + broadcast	20.9(401)	8.6(62)	8.9(63.00)	5.1(19.89)	16.6(249)	13.9(169)	4.4(12.0)	10.2(86.6)
PGS+ broadcast+ PE	19.9(358)	11.1(109)	8.4(55.91)	6.6(35.94)	15.7(219)	13.1(147)	4.3(10.9)	9.6(74.8)
PGS + PE	18.2(295)	10.0(85)	7.2(39.17)	5.3(21.35)	16.1(232)	13.7(175)	4.4(12.0)	10.1(92.7)
PGS + wheel hoe	13.0(145)	9.8(79)	4.9(15.61)	5.5(24.55)	10.1(86)	11.2(109)	2.8(3.5)	8.2(56.2)
LSD (p=0.05)	1.62	NS	0.82	NS	2.34	NS	0.72	1.82

*Data were subjected to square root transformation($\sqrt{x+1}$) Original values are in parentheses, Interaction LSD (p=0.05) = NS
PE=Plant extract, PGS=pre-germinated seeds, DAS=Days after sowing

treatments at both the locations. This could be attributed to lesser weed pressure (**Table 1**) because of removal of weeds with wheel hoe which resulted in an early suppression of weeds by crop and also influenced yield attributes and ultimately the yield positively. At location I, PGS+PE (3.77 t/ha) and PE (3.74 t/ha), statistically at par with each other; had significantly higher grain yield than PGS + broadcast (3.15 t/ha) and weedy check (3.21 t/ha). At location II, PGS+PE (3.72 t/ha), PE (3.45 t/ha), and PGS + broadcast + PE (3.44 t/ha), statistically at par with each other, had significantly higher grain yield than PGS + broadcast (2.82 t/ha) and weedy check (2.85 t/ha). The results indicated that though the PGS and plant extract combinations were inferior to hand weeding and PGS + wheel hoe but were significantly better than the weedy check indicating their potential in organic weed management programme particularly under labour constrained situations. PGS+PE resulted in an increase in grain yield by 17.66% at location I and 30.73% at location II compared to weedy check which can be attributed to negative effect of this treatment on weeds and positive on crop. Arif *et al* (2015) also reported improved wheat grain yield with water extract mixture of sorghum, sunflower and brassica. The comparatively better effect of plant extract at location II could be attributed to more grassy weeds which were suppressed better than broad-leaf weeds. The other reason could be the higher soil organic carbon content at location I which might have led to vigorous growth of weeds and thus comparatively their lesser suppression. PGS + broadcast recorded the lowest grain yield and it was statistically at par with weedy check and PGS + broadcast + PE at location I and with weedy check only at location II (**Table 2**). At location II, PGS + broadcast + PE was significantly better than weedy check. PGS + broadcast recorded the lower grain yield even than weedy check sown in lines and this might be due to more weed competition (**Table 1**) and less uniformly placed plants as compared to line sowing. Farooq and Cheema (2014) and Tomar *et al* (2020) also reported lower yield in broadcasting as a method of sowing compared to line sowing.

Both varieties had significant effect on harvest index at location II only where PBW 677 had significantly higher harvest index than Unnat PBW 550 (**Table 2**). Among the weed management practices, hand weeding recorded significantly higher harvest index than all the other treatments at both the locations. This could be attributed to higher grain yield in this treatment due to lesser weed competition (**Table 1, 2**). Better weed inhibition leads to better nutrient uptake by crop resulting in higher yield which ultimately enhances harvest index (Arif *et al* 2015). Among rest of the treatments at location I, PGS + wheel hoe had higher harvest index which was statistically at par with PGS + broadcast + PE and PGS+PE. Weedy check had significantly lower harvest index than all the other treatments except PE and PGS + broadcast. At location II, among rest of the treatments, PGS + wheel hoe had higher harvest index which was statistically at par with all the other treatments except weedy check and PGS + broadcast. Weedy check had significantly lower harvest index than all the other treatments except PE and PGS + broadcast. The lowest harvest index in weedy check and PGS + broadcast might be due to lesser grain yield (**Table 2**) due to more weed competition (**Table 1**). The lower harvest index in PE might be due to more straw yield compared to grain

Table 2. Effect of wheat varieties and weed management treatments on yield attributes, grain yield and harvest index of wheat

Treatment	Location I						Location II					
	Ear length (cm)	No. of grains per ear	Effective tillers (/m^2)	Thousand grain weight (g)	Grain yield (t/ha)	Harvest index (%)	Ear length (cm)	No. of grains per ear	Effective tillers (/m^2)	Thousand grain weight (g)	Grain yield (t/ha)	Harvest index (%)
Variety												
Unnat PBW 550	11.77	50.67	371.5	40.74	3.78	30.24	10.04	42.44	357.3	38.71	3.36	28.66
PBW 677	12.02	50.14	391.0	48.04	4.06	29.62	10.27	41.21	373.1	41.40	3.88	30.47
LSD (p=0.05)	NS	NS	NS	1.80	0.24	NS	NS	NS	NS	1.59	0.18	1.34
Weed management												
Weedy check	11.37	43.36	336.1	38.51	3.21	26.81	9.89	36.78	325.0	36.98	2.85	26.43
Hand weeding	12.10	58.00	432.8	46.13	5.44	35.87	10.49	44.92	412.8	44.34	4.73	34.08
PE	12.03	50.73	406.1	44.64	3.74	29.15	10.07	42.23	375.0	39.60	3.45	28.74
PGS + broadcast	12.00	46.76	308.8	43.83	3.15	27.36	10.00	40.82	304.7	37.69	2.82	27.06
PGS + broadcast + PE	11.73	47.57	350.7	46.18	3.56	29.59	10.10	41.72	367.7	38.90	3.44	29.59
PGS + PE	11.87	50.57	415.0	45.28	3.77	29.20	10.12	42.32	381.2	39.26	3.72	29.87
PGS + wheel hoe	12.17	55.83	419.4	46.13	4.58	31.53	10.44	44.00	390.2	43.61	4.32	31.21
LSD (p=0.05)	NS	6.99	83.1	3.36	0.44	2.35	NS	4.82	47.1	2.98	0.34	2.50

* PE=Plant extract, PGS=pre-germinated seeds, Interaction CD (p=0.05) = NS

Table 3. Effect of wheat varieties and weed management treatments on economics of wheat

Treatment	Economics							
	Location I				Location II			
	Cost of production (x10^3 `/ha)	Gross returns (x10^3 `/ha)**	Net returns (x10^3 `/ha)**	B : C ratio	Cost of production (x10^3 `/ha)	Gross returns (x10^3 `/ha)**	Net returns (x10^3 `/ha)**	B : C ratio
Variety								
Unnat PBW 550	32.25	105.04	72.79	3.23	32.25	93.59	61.34	2.89
PBW 677	31.87	112.49	80.62	3.53	31.87	107.62	75.75	3.38
Weed management								
Weedy check	29.60	89.51	59.91	3.03	29.60	79.82	50.21	2.70
Hand weedings	41.85	149.74	107.89	3.58	41.85	130.54	88.69	3.12
PE	31.35	103.84	72.48	3.31	31.35	96.16	64.80	3.07
PGS + broadcast	28.57	87.94	59.36	3.08	28.57	78.99	50.42	2.77
PGS + broadcast + PE	30.32	99.12	68.80	3.27	30.32	95.74	65.42	3.16
PGS + PE	31.35	104.78	73.43	3.34	31.35	103.42	72.06	3.30
PGS + wheel hoe	31.35	126.43	95.08	4.03	31.35	119.58	88.22	3.82

*PE=Plant extract, PGS=Pre-germinated seeds, B: C ratio= Benefit-cost ratio.** Organic wheat produce price (₹ 26950/t) was subjected to 40% increase due to organic produce compared to wheat minimum support price (₹ 19250/t), *** Costs/prices= farm yard manure ₹ 1000/ton; seed ₹ 30/kg; seed treatment = beejamrit (₹ 415/ha seed); land preparation + sowing method = line sowing – drill (₹ 6250/ha), broadcast sowing (₹ 5220/ha); insecticide - neemkavach (₹ 350/L); Extract preparation (two times) = ₹ 1000/ha, labour ₹ 350/person/day, two wheel hoeing ₹ 1750/ha; two hand weedings (₹ 12250/ha) spray charges = ₹ 1/L, two sprays of plant extract ₹ 750, two sprays of neemkavach ₹ 500; harvesting ₹ 5000/ha, grains 26950/t, straw ₹ 3000/ha.

yield as plant extract application might have enhanced straw yield (**Table 2**) due to increased plant height.

Economic analysis

Economics plays an important role in final evaluation of a treatment. There was a slight higher cost of cultivation in Unnat PBW 550 due to more seed rate (112.5 kg/ha) compared to PBW 677 (100 kg/ha). However, the gross returns, net returns and B: C were higher in PBW 677 than Unnat PBW 550 (**Table 3**). This was due to higher grain yield and comparatively less cost of cultivation in PBW 677.

Among the weed management practices, the highest cost of cultivation was with hand weeding twice, at both the locations due to labour involved while the lowest cost was in PGS + broadcast. Hand weeding had the higher gross and net returns but the B : C was higher in PGS + wheel hoe. At location II, the B : C of PGS + PE and PGS + broadcast + PE was also higher than hand weeding.

It may be concluded that the taller wheat variety PBW 677 proved better than Unnat PBW 550 in respect of weed management, grain yield, net returns and B : C ratio. Hand weeding twice at 30 and 60 DAS provided the most effective management of weeds followed by line sowing of pre-germinated wheat seeds+ two wheel hoeing- one before first irrigation and second at about 55 DAS. Under labour constrained situations, line sowing of pre-germinated wheat seeds + foliar application of sorghum + sunflower + raya extract at 18 L/ha each at 25 and 50 DAS can be a viable option for weed management in organic wheat production.

REFERENCES

Anonymous 2022. https://www.indiastat.com/table/wheat/area-production-productivity-wheat-india-1949-1950/7400

Anonymous 2022a. *Package of Practices for Crops of Punjab – Rabi 2021-22*. Punjab Agricultural University, Ludhiana, Pp 2.

Abbas T, Nadeem MA, Tanveer A and Chauhan BS. 2017. Can hormesis of plant-released phytotoxins be used to boost and sustain crop production? *Crop Protection* **93**: 69–76.

Arif M, Cheema ZA, Khaliq A and Hassan A. 2015. Organic weed management in wheat through allelopathy. *International Journal of Agriculture and Biology* **17**: 127–134.

Ashraf R, Sultana B, Yaqoob S and Iqbal M. 2017. Allelochemicals and crop management: A review. *Current Science* **3**: 1–13.

Aulakh CS and Ravisankar N. 2017. Organic farming in Indian context: A perspective. *Agricultural Research Journal* **54** (2): 149–164.

Awan FK, Rasheed M, Ashraf M and Khurshid YM. 2012. Efficacy of brassica, sorghum and sunflower aqueous extracts to control wheat weeds under rainfed conditions of Pothwar, Pakistan. *Journal of Animal and Plant Sciences* **22**: 715–721.

Bhullar MS, Kaur N, Kaur P and Gill G. 2017. Herbicide resistance in weeds and its management. *Agricultural Research Journal* **54** (4): 436–444.

Bogatek R, Gniazdowska A, Zakrzewska W, Oracz K and Gawronski SW. 2006. Allelopathic effects of sunflower extracts on mustard seed germination and seedling growth. *Biologia Plantarum* **50**: 156–158.

Bond W and Grundy AC. 2001. Non-chemical weed management in organic farming systems. *Weed Research* **41**: 383–405.

Borras L, Slafer GA and Otegui ME. 2004. Seed dry weight response to source-sink manipulations in wheat, maize and soybean: a quantitative reappraisal. *Field Crop Research* **86**: 131–146.

Calabrese EJ. 2005. Paradigm lost, paradigm found: the re-emergence of hormesis as a fundamental dose response model in the toxicological sciences. *Environmental pollution* **138**: 378–411.

Cheema ZA and Khaliq A. 2000. Use of sorghum allelopathic properties to control weeds in irrigated wheat in a semi-arid region of Punjab. *Agriculture, Ecosystems and Environment* **79**: 105–112.

Cheema ZA, Sadiq HMI and Khaliq A. 2000a. Efficacy of *sorgaab* (sorghum water extract) as a natural weed inhibitor in wheat. *International Journal of Agriculture and Biology* **2**: 144–146.

Chhokar RS, Sharma RK and Sharma I. 2012. Weed management strategies in wheat-A review. *Journal of Wheat Research* **4**(2): 1–21.

Farooq N, Abbas T, Tanveer A and Jabran K. 2020. Allelopathy for Weed Management. In: Mérillon JM., Ramawat K. (eds) *Co-Evolution of Secondary Metabolites. Reference Series in Phytochemistry*. Springer, Cham.

Farooq O and Cheema ZA. 2014. Influence of sowing dates and planting methods on weed dynamics in wheat crop. *Pakistan Journal of Agricultural Sciences* **51**(4): 817–825.

Glab L, Sowiñski J, Bough R and Dayan FE. 2017. Allelopathic potential of sorghum (*Sorghum bicolor* (L.) Moench) in weed control: A comprehensive review. *Advances in Agronomy* **145**: 43–95.

Hussain S. 2015. *Effects of allelopathic crop water extracts with low doses of herbicides on weeds and yield of rainfed wheat and groundnut*. Dissertation, Pir Mehr Ali Shah Arid Agriculture University Rawalpindi, Pakistan.

Jabran K, Mahajan G, Sardana V and Chauhan BS. 2015. Allelopathy for weed control in agricultural systems. *Crop Protection* **72**: 57–65.

Korres NE and Froud-Williams RJ. 2002. Effects of winter wheat cultivars and seed rate on the biological characteristics of naturally occurring weed flora. *Weed Research* **42**: 417–428.

Kumar S, Malik RS, Yadav A and Malik RK. 2007. Performance of cultivars and sulfosulfuron against weeds in wheat. *Indian Journal of Weed Science* **39**: 44–47.

Meulen AV and Chauhan BS. 2017. A review of weed management in wheat using crop competition. *Crop Protection* **95**: 38–44.

Ramesh K, Rao AN and Chauhan BS. 2017. Role of crop competition in managing weeds in rice, wheat, and maize in India: A review. *Crop Protection*. **97**: 14–21.

Sandhu KS, Kolar JS and Singh G. 1981. Studies on cultural control of wild oats (*Avena ludoviciana* Dur.), a grassy weed in wheat. *Indian Journal of Weed Science* **13**(2): 146–149.

Singh M. 2021. Organic farming for sustainable agriculture. *Indian Journal of Organic Farming* **1**: 1–8.

Tomar V, Panotra N, Tomer R and Singh G. 2020. Effect of different herbicides and planting techniques on yield and yield components in late sown wheat (*Triticum aestivum* L.*). Journal of Pharmacognosy and Phytochemistry* **9**(2): 2044–2047.

Vigar V, Myers S, Oliver C, Arellano J, Robinson S and Leifert C. 2020. A Systematic Review of Organic Versus Conventional Food Consumption: Is There a Measurable Benefit on Human Health? *Nutrients* **12(1)**: 7.

Weston LA, Alsaadawi IS and Baerson SR. 2013. Sorghum allelopathy- from ecosystem to molecule. *Journal of Chemical Ecology* **39**: 142–153.