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RESPONSE OF WHEAT AND WINTER WEEDS TO FOLIAR APPLICATION OF DIFFERENT PLANT WATER EXTRACTS OF SORGHUM *(S. bicolor)*

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ABSTRACT

Allelopathy has been explored recently as a substitute for chemical herbicides to reduce environmental pollution. Various plant water extracts alone and in combinations with each other may exert their influence differently on weeds and crop plants. Response of wheat and its weeds to foliar application of sorghum (Sorghum bicolor), sunflower (Helianthus annuus) and eucalyptus (Eucalyptus camaldulensis) water extracts individually and in combinations with each other at different doses were tested under field conditions. Concentrated sunflower water extract @ 12 L ha^{-1} sprayed at 30 and 40 days after sowing gave consistently better weed control and increased wheat yield by 5.5% over control. A combination of water extracts of sorghum, sunflower and eucalyptus each @ 12 L ha^{-1} and 8 L ha^{-1} were also economical. However, conventional methods like hand weeding and herbicides, though effective in weed control, were uneconomical due to higher costs.

Key words: Allelopathy, plant water extracts, wheat, weed control, net income.

INTRODUCTION

Allelopathy is being utilized in agriculture in various ways i.e. allelopathic stubble mulches, allelopathic crops in rotation and inter/mixed cropping systems (Fortney and Foy, 1985; Cheema, 1988; Narwal, 2000). A relatively new approach is to use foliar sprays of different allelopathic water extracts for inhibiting weeds in field crops (Iqbal, 1997; Cheema and Ahmad, 1992; Dur-e-Shahwar, 1996). Reduction in weed biomass by 33-53% and increase in wheat yield (7-14%) by application of sorghum (*Sorghum bicolor*) and sunflower *(Helianthus annuus)* water extracts was reported (Cheema *et al.*, 1997). Similar observations were made in other crops (Bhatti *et al.*, 2000; Khaliq *et al.*, 1999). The allelochemicals present in one plant water extract might act synergistically with the allelochemicals of another plant water extract. Mixture of vanillic and p-hydroxybenzoic acids reduced radish seed germination by 48% whereas individually they reduced seed germination by 29% and 5%, respectively (Einhellig and Rasmussen; 1978). Equimolar concentration of 3.3 mM of each of ferulic, p-coumaric and vanillic acids exerted a synergistic inhibition of sorghum seed germination; however this concentration did not have synergistic effect on seedling growth which might have resulted from the stimulatory effect exhibited by the 3.3 mM concentration of vanillic acid on seedling growth (Rasmussen and Einhellig, 1979). Similarly there was little effect of any phenolic compound at 10^{-5} M. At 10^{-3} M, coumarin, hydrocinnamic acid, juglone and pyrocatechol strongly inhibited seed germination of test crop and weed species. The combination of coumarin and p-hydroxybenzaldehyde had an additive effect on germination of two weed species, inhibiting germination to a greater extent than either compound alone (Williams and Hoagland, 1982).

The objectives of the instant studies were to evaluate the effect of aqueous extracts of allelopathic plants such as sorghum *(Sorghum bicolor)*, sunflower *(Helianthus annuus)* and eucalyptus *(Eucalyptus camaldulensis)* on wheat weeds and to evaluate any possible synergistic effect by combining these extracts on growth of wheat and its weeds under field conditions.

MATERIALS AND METHODS

The experiment was conducted at agronomic research area, University of Agriculture, Faisalabad during 2001-2002. Sorghum *(S. bicolor)* and sunflower *(H. annuus)* herbage and eucalyptus *(E.*

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camaldulensis leaves were harvested at maturity and dried. Sorghum and sunflower herbage was chaffed into 2 cm pieces and eucalyptus leaves were ground. Chaffed herbage and ground leaves were soaked in distilled water in the ratio of 1:10 (w/v) for 24 hrs and then filtered to collect [illegible] respective water extracts. The extracts were concentrated to 20 times by boiling at 100 °C [illegible] Wheat variety Iqbal 2000 was sown in 25 cm spaced rows with single row hand drill [illegible] on November 1, 2001. Treatments were arranged in randomized complete block design with four replications. Recommended cultural practices were followed for all the treatments [illegible] The three aqueous extracts alone and in combinations with each other [illegible] herbicide were sprayed on the standing wheat and weeds with knapsack hand sprayer fitted with flat fan nozzle calibrated to 357 liters per hectare. The plant water extracts used were [illegible] concentrated sorgaab (SorWE), concentrated sunflower water extract (SunWE) and concentrated eucalyptus water extract (EuWE) each @ 12 L ha⁻¹ at 30 and 40 days after sowing (DAS) and combined spray of these concentrated water extracts each @ 6, 8 and 16 L ha⁻¹ [illegible] at 30 DAS. Isoproturon was applied @ 1 kg a.i. ha⁻¹ and one hand weeding was done [illegible] weedy check was maintained as control treatment. Data on weed density and biomass [illegible] at 45 DAS and 60 DAS from randomly selected two quadrates (50 x 50 cm) [illegible] experimental unit. The dry weight of weeds was taken after drying in an oven at 80 °C [illegible] on various wheat growth parameters were recorded from randomly selected samples using standard procedures and grain yield per plot was obtained by [illegible] converted to t ha⁻¹.

Data collected were analyzed by using Fisher's analysis of variance technique (Steel and Torrie [illegible]). Economic analysis of the treatments was done to determine the most economical treatment [illegible].

RESULTS AND DISCUSSION

[illegible] of the experimental site were canary grass (*Phalaris minor*) and wild oat [illegible] (*Melilotus parviflora*) and broad leaved dock (*Rumex dentatus*) [illegible]

[illegible] was reduced upto 78 and 72% by isoproturon and hand weeding respectively. [illegible] water extracts, combinations of SorWE + SunWE + EuWE [illegible] consistently effective, followed by SunWE (two sprays) which although was [illegible] at 45 DAS yet reduced total weed density by 34% at 60 DAS. Isoproturon, hand weeding [illegible] water extracts each @ 6 L ha⁻¹ were effective treatments in suppressing density of [illegible] and 47% suppressions, respectively. Wild oat density was suppressed [illegible] though promoting at 45 DAS, was inhibitory up to [illegible] at 60 DAS [illegible] oat density by SorWE confirm the findings of Iqbal (1997) and Qadir (2000) who [illegible] of wild oat density by application of sorgaab (SorWE). Density of sweet [illegible] effectively by isoproturon and hand weeding. Most water extract treatments were [illegible] at 45 DAS but slightly stimulating at 60 DAS. Broad leaved dock was greatly suppressed [illegible] isoproturon and hand weeding, followed by combination of SorWE + SunWE + EuWE each [illegible] causing 68% reduction at 60 DAS).

[illegible] dry weight was inhibited greatly by hand weeding and isoproturon by 67.75% and 50.71 [illegible] respectively. Combination of water extracts each @ 16 L ha⁻¹ was the next best treatment causing up [illegible] reduction in total weed dry weight (Table 2). Dry weight of canary grass was greatly controlled [illegible] and hand weeding (83-100 and 75.91%, respectively) followed by combination of [illegible] L ha⁻¹ causing up to 40% reduction. Certain water extracts as EuWE [illegible] water extracts each @ 6 L ha⁻¹, 8 and 16 L ha⁻¹ and [illegible] hand weeding which gave maximum control in controlling dry weight of [illegible] by mixture applications is in lines with findings of [illegible] who [illegible] that combinations of allelochemicals have synergistic effect [illegible] was controlled effectively by isoproturon (100%) and hand weeding [illegible] water extracts each at 16 L ha⁻¹ gave 34.48%.

Table 1. Effect of various plant water extracts on density of different weed species

Treatments	*Density (number per 50 cm²)*									
	Total weeds		Canary grass		Wild oats		Sweet clover		Broad-leaved dock	
	45 DAS	60 DAS	45DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS
Control (weedy check)	80.38[1] ab	89 25 a	26.13 a	24.38 bc	15 75 b	27 0 a	18 88 a	10 63 abc	6.38[n.s]	5 63 a
SorWE @ 12 L ha[-1] at 30 & 40 DAS	83 38 a (+4.35)[2]	74.5 ab (-16.53)	28.0 a (+7 16)	30.0 a (+23 05)	22 38 a (+42 09)	14 38 bc (-46 74)	16 88 ab (-10 59)	7 25 bc (-31 8)	5.88	3.75 ab (-33.39)
SunWE @ 12 L ha[-1] at 30 & 40 DAS	53 38 c (-33.59)	89.88 a (0)	16 13 bcd (-38 27)	27 5 ab (+12 8)	14 13 b (10 29)	25.13 ab (-6 92)	13 0 bcc (-31 14)	11.13 abc (+4.7)	3 38	5.75 a (+2.13)
EuWE @ 12 L ha[-1] at 30 & 40 DAS	67 63 bc (-15 86)	81 63 ab (-8 54)	25 63 ab (-1.91)	23.5 cd (-3 6)	14 13 b (-10 29)	21 63 ab (-19 89)	13 75 bcd (-27 17)	13.88 a (+30 57)	6 25	3.88 ab (-31.08)
SorWE + SunWE + EuWE each @ 6 L ha[-1] at 30 DAS	58.25 c (-27.53)	75.0 ab (-15.97)	15.5 cd (-40.68)	22 5 cd (-7.7)	17.25 ab (+9.52)	21 13 ab (-21 74)	14 63 abc (-22 51)	11 13 abc (+4 7)	4.63	2 38 bc (-57.73)
SorWE + SunWE + EuWE each @ 8 L ha[-1] at 30 DAS	64.25 c (-20 07)	70 63 b (-20.86)	24 5 abc (-6 24)	21.5 cd (-11.81)	13.13 b (-16 63)	18 88 abc (-30 07)	12 25 cd (-35.12)	10.5 abc (-1.22)	7 0	3.75 ab (-33.39)
SorWE + SunWE + EuWE each @ 12 L ha[-1] at 30 DAS	59.88 c (-25.5)	81 5 ab (-8.68)	19.38 abc (-25.83)	20.63 d (-15 38)	14 88 b (-5 52)	23 38 ab (-13 41)	12 38 bcd (-34.43)	11.88 ab (+11.76)	6 38	3.88 ab (-31.08)
SorWE + SunWE + EuWE each @ 16 L ha[-1] at 30 DAS	64 75 c (-19 45)	72.25 b (-19.05)	27.0 a (+3 3)	22 63 cd (-7 18)	14 0 b (-11 11)	21 13 ab (-21.74)	9.38 d (-50 32)	10 5 abc (-1 22)	4.75	5.25 a (-6.74)
Isoproturon @ 1 kg a i ha[-1] at 30 DAS	31.63 d (-60 65)	19 75 d (-77 87)	9 13 d (-65.08)	3.25 f (-86.67)	15 38 b (-2.35)	9 5 c (-64 81)	1 13 c (-94 01)	1 38 d (-87 02)	0.00	0 00 c (-100)
Hand weeding at 30 DAS	22 5 d (72 0)	41.13 c (-53.92)	7.0 d (-73.21)	15.75 e (-35.40)	6.0 c (-61.9)	8 5 c (-68 52)	2 5 e (-86 76)	6 13 cd (-42.33)	4.38	1.63 bc (-71 05)
L S D (5%)	15 19	16 68	9 789	3 30	6 24	11 24	4 54	5 44		2 73

[1] Means with different letters differ significantly at 5%; [2] in parenthesis % increase or decrease over control is shown; SorWE = Sorghum water extract conc.; SunWE = Sunflower water extract conc.; EuWE = Eucalyptus water extract conc.; DAS = Days after sowing; n.s. = non-significant.

reduction in sweet clover dry weight. Dry weight of broad-leaved dock was suppressed upto 100 and 86% by isoproturon and hand weeding, respectively followed by combination of water extracts each @ 12 L ha^{-1} and SunWE (two sprays) giving upto 72 and 65% control, respectively. Water extracts exhibited differential effects on wheat growth (Table 3). Isoproturon, SunWE (two sprays) and hand weeding were statistically similar treatments causing 31, 23 and 20% increase in leaf area index over control. This may be either due to better weed control by the three treatments and/or promoting effect by SunWE on wheat crop. Ghafar *et al.* (2000) also reported stimulatory and inhibitory effect of SunWE on wheat at different concentrations. Similarly higher number of grains per spike was obtained in isoproturon, combination of SorWE + SunWE + EuWE each @ 12 L ha^{-1} and SunWE (two sprays) treated plots (statistically similar treatments) giving 6, 4 and 3% increase over control. The other treatments were statistically similar to control; this may be due to concentration dependent and synergistic effects of various allelochemicals as described by Nandal *et al.* (1992), Rice *et al.* (1981) and Einhellig *et al.* (1982). Treatments yielding higher number of grains per spike yielded less 1000-grain weight e.g. it decreased very much in treatments like isoproturon, combination of water extracts each @ 12 L ha^{-1} and SunWE (two sprays). This is in accordance with the findings of Frederick and Camberato (1995) and Slafer and Andrade (1993) describing inverse relationship between grain number per spike and grain weight.

Isoproturon, SunWE (two sprays), hand weeding, combinations of SorWE + SunWE +EuWE each @ 16 and 12 L ha^{-1} were among the higher grain yield giving treatments. The maximum increase was achieved in isoproturon treated plot (6.4%) followed by SunWE (5.5%) confirming the results of Cheema *et al.* (1997) and Cheema and Khaliq (2000). Economic and marginal analyses (Table 4&5) show that SunWE concentrated applied @ 12 L ha^{-1} (two sprays at 30 and 40 DAS) was the most economical and best treatment with higher net benefits (Rs. 28395 ha^{-1}) and maximum marginal rate of return (7797.5%). Combinations of SorWE + SunWE + EuWE each @ 8 and 12 L ha^{-1} were also economical treatments due to 6.6 and 523% marginal return, respectively. The other extracts were uneconomical and it is worthwhile to state here that EuWE @ 12 L ha^{-1} (two sprays) caused 19.8% reduction in wheat yield due to suppressive allelopathic effect. This is in accordance with findings of Bansal *et al.* (1992) reporting concentration dependent activity of eucalyptus against wheat. On the basis of present study it is suggested that using crop water extracts for controlling weeds is economical and environment friendly and combining water extracts at appropriate dose exerts positive influence on wheat.

Table 2: Effect of various plant water extracts on dry weight of different weed species.

Treatments	Dry weight (g 50 cm^{-2})									
	Total weeds		Canary grass		Wild oats		Sweet clover		Broad-leaved dock	
	45 DAS	60 DAS	45DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS	45 DAS	60 DAS
Control (weedy check)	0.406[1] bcd	1 728 a	0 081 abc	0.548 a	0 225 a	0.718 abc	0.063 a	0.116 ab	0 018[ns]	0.091[ns]
SorWE @ 12 L ha^{-1} at 30 & 40 DAS	0.552 ab (+ 35.96)[2]	1 881 a (+8 85)	0.119 a (+46 91)	0 608 a (+10 95)	0 279 a (+1 78)	0.95 a (+32.31)	0.066 a (+4.76)	0 085a b (-26 72)	0 025	0.097
SunWE @ 12 L ha^{-1} at 30 & 40 DAS	0 397 bcd (- 2 22)	1.799 a (+4.1)	0 079 abc (-2 47)	0.514 a (-6 20)	0 186 ab (-17 33)	0.748 ab (+4.18)	0.04 ab (-36.51)	0.138a b (+18.96)	0.006 3	0.069
EuWE @ 12 L ha^{-1} at 30 & 40 DAS	0.584 ab (+43.84)	1 335 a (-22.74)	0 113 a (+39 51)	0.37 ab (-32 48)	0.33 a (+46 67)	0 445 cd (-38 02)	0 066 a (+4 76)	0.139 a (+19.83)	0.023	0.073
SorWE + SunWE + EuWE each @ 6 L ha^{-1} at 30 DAS	0 722 a (+77.83)	1 385 a (-19 85)	0 113 a (+39 51)	0 514 a (-6 2)	0 206 a (-8 44)	0.491 bcd (-31 62)	0.053 a (-15 87)	0.104a b (-10.34)	0 011	0.056
SorWE + SunWE + EuWE each @ 8 L ha^{-1} at 30 DAS	0 349 bcd (-14 04)	1.629 a (-5 73)	0.091 ab (+12.34)	0.589 a (+7.48)	0.179 ab (-20.44)	0.531 bcd (-26.04)	0.066 a (+4 76)	0.103a b (-11.21)	0.013	0.051
SorWE + SunWE + EuWE each @ 12 L ha^{-1} at 30 DAS	0.431 bc (+6.16)	1.504 a (-12 96)	0 057 abc (-29 63)	0 466 a (-14 96)	0 158 ab (-29 78)	0.733 abc (+2 09)	0.049 a (-22 22)	0.081a b (-30 17)	0.005	0 06
SorWE + SunWE + EuWE each @ 16 L ha^{-1} at 30 DAS	0 424 bc (+4 43)	1 136 ab (-34 26)	0 114 a (+40 74)	0 506 a (-7 66)	0 216 a (-4 0)	0 494 bcd (-31 19)	0 033 abc (-47.62)	0 076 b (-34.48)	0 021	0.049
Isoproturon @ 1 kg a i ha^{-1} at 30 DAS	0 201 cd (-50 49)	0.508 b (-70 6)	0 03 bc (-62 96)	0 0 C (-100)	0 118 ab (-47 56)	0 505 bcd (-29 67)	0 0 C (-100)	0.0 C (-100)	0.007 5	0 00
Hand weeding at 30 DAS	0 132 d (-67 49)	0 44 b (-74 54)	0 02 c (-75 31)	0 049 bc (-91 06)	0 058 b (-74 22)	0 325 d (-54 73)	0 008 bc (-87 3)	0 01 C (-91 38)	0 003 8	0 013
L S D. (5%)	0 283	0 77	0 068	0 367	0 142	0 297	0 034	0 063	-	-

[1] Means with different letters differ significantly at 5%; [2] in parenthesis % increase or decrease over control is shown. SorWE = Sorghum water extract conc.; SunWE = Sunflower water extract conc. EuWE = Eucalyptus water extract conc.; DAS = Days after sowing; n s. = non-significant

Table 3. Effect of various plant water extracts on growth parameters and yield of wheat.

Treatments	Leaf Area Index	No. of grains per spike	1000-grain weight (g)	Grain yield (t ha^{-1})
Control (weedy check)	2.57[1] b	51.53 cd	37.01 ab	4.038 c
SorWE @ 12 L ha^{-1} at 30 & 40 DAS	2.19 cd (-14.75)[2]	52.0 cd (+0.91)	36.81 abc (-0.54)	4.102 bc (+1.58)
SunWE @ 12 L ha^{-1} at 30 & 40 DAS	3.15 a (+22.61)	53.25 ab (+3.34)	34.81 d (-5.94)	4.26 ab (+5.50)
EuWE @ 12 L ha^{-1} at 30 & 40 DAS	2.60 b (+1.10)	51.64 cd (+0.21)	32.44 e (-12.35)	3.24 d (-19.76)
SorWE + SunWE + EuWE each @ 6 L ha^{-1} at 30 DAS	1.91 d (-25.88)	52.66 bc (+2.19)	35.74 bcd (-3.43)	4.074 c (+0.89)
SorWE + SunWE + EuWE each @ 8 L ha^{-1} at 30 DAS	2.20 c (-14.51)	51.58 cd (+0.10)	36.27 abcd (-2.00)	4.083 c (+1.11)
SorWE + SunWE + EuWE each @ 12 L ha^{-1} at 30 DAS	2.11 cd (-18.09)	53.76 ab (+4.33)	35.51 cd (-4.05)	4.143 abc (+2.60)
SorWE + SunWE + EuWE each @ 16 L ha^{-1} at 30 DAS	2.75 b (+6.96)	50.31 d (-2.37)	36.99 ab (-0.05)	4.178 abc (+3.47)
Isoproturon @ 1 kg a.i. ha^{-1} at 30 DAS	3.37 a (+31.17)	54.58 a (+5.92)	35.08 d (-5.21)	4.298 a (+6.44)
Hand weeding at 30 DAS	3.08 a (+19.92)	50.56 d (-1.88)	37.52 a (+1.38)	4.205 abc (+4.14)
L.S $D_{0.05}$	0.29	1.73	1.46	0.172

[1] Means with different letters differ significantly at 5%; [2] in parenthesis % increase or decrease over control is shown; SorWE = Sorghum water extract conc.; SunWE = Sunflower water extract conc.; EuWE = Eucalyptus water extract conc ; DAS = Days after sowing; n.s. = non-significant.

Table 4. Economic analysis of different weed control methods in wheat.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Remarks
Total grain yield	4038	4102	4260	3240	4074	4083	4143	4178	4298	4205	kg ha^{-1}
Adjusted yield	3634.2	3691.8	3834.0	2916.0	3666.6	3674.7	3728.7	3752.7	3868.2	3784.5	kg ha^{-1}(10% reduction)
Gross income (ha^{-1})	27256.5	27688.5	28755	21870	27499.5	27560.25	27965.25	28145.25	29011.5	28383.75	Wheat grain price @ Rs. 750/100 kg
Cost of SorWE	-	100	-	-	-	-	-	-	-	-	Rs. 40/40 kg Sorghum herbage+ SorWE preparation
Cost of SunWE	-	-	100	-	-	-	-	-	-	-	Rs. 40/40 kg Sunflower herbage+ SunWE preparation
Cost of EuWE	-	-	-	80	-	-	-	-	-	-	Rs. 40/40 kg Eucalyptus leaves + EuWE preparation
Cost of mixture	-	-	-	-	125	155	220	250	-	-	combining respective doses of water extracts
Cost of Herbicide	-	-	-	-	-	-	-	-	840	-	Rs. 840/1kg a.i.
Spray application cost	-	160	160	160	80	80	80	80	80	-	Rs. 80/man (one man /day/ha)
Spray rent	-	100	100	100	50	50	50	50	50	-	Rs. 50/spray
Cost of Hand weeding	-	-	-	-	-	-	-	-	-	800	Rs. 80/man and 10 men/ha
Cost that vary	-	360	360	340	255	285	350	380	970	800	Rs. ha^{-1}
Net benefit	27256.5	27328.5	28395	21530	27244.5	27275.25	27615.25	27765.25	28041.5	27583.75	Rs. ha^{-1}

T_1 = Control (weedy check); T_2 = SorWE @ 12 L ha^{-1} at 30 & 40 DAS; T_3 =SunWE @ 12 L ha^{-1} at 30 & 40 DAS;T_4 = EuWE @ 12 L ha^{-1} at 30 & 40 DAS; T_5 = SorWE +SunWE + EuWE each @ 6 L ha^{-1} at 30 DAS; T_6 = SorWE +SunWE + EuWE each @ 8 L ha^{-1} at 30 DAS; T_7 = SorWE + SunWE + EuWE each @ 12 L ha^{-1} at 30 DAS; T_8 = SorWE + SunWE + +EuWE each @ 16 L ha^{-1} at 30 DAS; T_9 = Isoproturon @ 1kg a.i. ha^{-1} at 30 DAS; T_{10} = Hand weeding at 30 DAS

Table 5: Marginal analysis of different weed control methods in wheat.

Treatments	Varying Costs (Rs. Ha^{-1})	Net benefit (Rs. ha^{-1})	Marginal rate of return (%)
Control	0	27256.5	
SorWE + SunWE + EuWE each @ 6 L ha^{-1}	255	27244.5	D
SorWE+ SunWE+ EuWE each @ 8 L ha^{-1}	285	27275.25	6.58
EuWE two sprays	340	21530	D
SorWE + SunWE + EuWE each @ 12 L ha^{-1}	350	27615.25	523.08
SunWE two sprays	360	28395.0	7797.5
SorWE two sprays	360	27328.5	D
SorWE + SunWE + EuWE each @ 16 L ha^{-1}	380	27765.25	D
Hand weeding	800	27583.75	D
Isoproturon	970	28041.5	D

D = Dominated;Marginal rate of return (MRR) % = Change in net benefits/Change in cost x 100; Cost that vary = The cost that is incurred on the variable inputs (weed control measures) in the production of a particular commodity (wheat);.SorWE= Sorghum water extract conc.; SunWE = Sunflower water extract conc.;EuWE = Eucalyptus water extract conc.; DAS = Days after sowing.

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