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Evaluation Of Early Post Emergence and Post Emergence Herbicides on Weed Control and Productivity of Direct Seeded Puddled Rice in Kuttanad

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Field experiments were conducted during *kharif* 2011 and *rabi* 2011 -12 at Rice Research Station, Moncompu, Kerala to study the efficacy of herbicides for weed control in direct seeded rice. The experiments were conducted in RBD with seven treatments comprising of two early post emergence herbicides, two post emergence herbicides, weed free situation, hand weeding twice at 20 and 40 DAS and unweeded check in plots of 25 m_2. The major weeds found in the experimental field were; *Echinochloa stagnina* (Retz.) P. Beauv., *Echinochloa glabrescens* Munro ex Hook. f., *Fimbristylis miliacea* (L.)Vahl, *Cyperus difformis* L., *Cyperus iria* L., *Schenoplectus pungens* (Vahl) Palla, *Monochoria vaginalis* (Burm. f.) C. Presl ex kunth, *Ludwigia perennis* L. and *Sphenoclea zeylanica* Gaertner. Results of the study indicated that predominance of weed flora depended on the season. Grassy weeds predominated during *kharif* season and sedges predominated during *rabi* season. All the weed control treatments significantly reduced the density and dry weight of weeds which resulted in significantly higher growth and yield of rice over unweeded control. Results also indicated that early post emergence herbicides like pyrazosulfuron ethyl 10% WP and bensulfuron methyl + pretilachlor (6.6 GR) were found effective in controlling sedges and broad leaved weeds, while the post emergence herbicides, bispyribac sodium was found effective against grassy weeds and broad leaved weeds and penoxsulam was found effective against grassy weeds and sedges. During both seasons weed free situation recorded the highest grain yield. Among the herbicide treatments, post emergence application of bispyribac sodium 10% SC @ 30 g ai/ha and penoxsulam24 SC @ 25 g ai/ha and early post emergence application of pyrazosulfuron ethyl 10 % WP @ 20 g ai/ha recorded higher yield which was on par with each other with better weed control efficiency and low weed index.

Key words: Direct seeded rice, weed density, weed dry matter, weed control efficiency, weed index

Weeds are the prime biological constraint in direct seeded rice, because both weed and crop seeds emerge at the same time and compete with each other from germination (Singh and Singh, 2010). Weeds compete with rice crop for space, water, light and nutrients. In direct seeded rice, the critical period of weed competition has been reported to be 15-45 days after sowing (DAS). Crop- weed competition during the critical period causes considerable yield losses. Weed control during the critical period of crop- weed competition is essential to reduce the weed competition and effective utilization of available resources for enhanced productivity of rice crop. Chatterjee and Maity (1981) reported that, in India rice grain production suffers yearly loss of 15 million tonnes due to weed competition. Uncontrolled weeds reduce the grain yield by 96% in dry direct seeded rice and 61 % in wet direct seeded rice (Maity and Chatterjee, 2008). Direct seeded rice could yield equal to those of transplanted rice, when weed control was optimum and crop establishment was good (Sipaseuth *et al*., 2000). Though manual weeding effective and it was labour intensive and tedious. It does not ensure weed removal at critical stages of crop-weed competition and bad weather conditions. Thus herbicide usage seems indispensable and an economic alternative method for weed control in direct seeded rice (Azmi *et al*., 2005). The continuous use of single herbicide or herbicide having same mode of action may lead to resistance problems in weeds. Keeping these views in mind, field experiments were conducted to evaluate the efficacy of early post emergence and post emergence herbicides in controlling the weeds in direct seeded rice under puddled irrigated condition of Kuttanad.

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Materials and Methods

Field experiments were conducted during *kharif* 2011(June -October) and *rabi* 2011-12 (December 2011-April 2012) at the experimental farm of Rice Research Station, Moncompu, Alappuzha, Kerala (geographically situated at 9º 5´ N latitude and 76º 5´E longitude and at an altitude 1 m below MSL). The soil of the experimental site was silty clay in texture with pH 6.2 (wet), O.C 1.5 %, available P 18 kg/ha and available K 135 kg/ha. The experiments were laid out in randomized block design with seven treatments

viz., penoxsulam 24 SC (25 g ai/ha) at 15 to 20 DAS (post emergence) (T_1), pyrazosulfuron ethyl 10 WP (20 g ai/ha) at 4 to7 DAS (early post emergence) (T_2), bispyribac sodium 10 SC (30 g ai/ha) at15 to 20 DAS (post emergence) (T_3), bensulfuron methyl + pretilachlor (6.6 GR) (0.06 +0.60 kg ai/ha) at 8 to 10 DAS (early post emergence) (T_4), weed free situation (hand weeding at 15, 30, 45 and 60 DAS) (T_5), hand weeding at 20 & 40 DAS (T_6) and unweeded control (T_7). The total rainfall received during the cropping season was 1555.6 mm and 387 mm, respectively during *kharif* 2011 and *rabi* 2011-12.

The pre-germinated seeds of medium duration rice variety 'Uma' were sown on 17 June 2011 and 8 December 2011. The seed rate adopted for sowing was 100 kg/ha. The crop was fertilized with 90-45-45 of N-P_2O_5-K_2O kg/ha. One third dose of N and K and half P was applied at 15 DAS, one third dose of N and K and half P at 35 DAS and remaining one third N and K at 55 DAS. All other agronomic measures were adopted as per the package of practice recommendations of Kerala. Herbicides were applied with the help of a hand operated knapsack sprayer fitted with flat fan nozzle at a spray volume of 300 l/ha. Observations on weed density was recorded with the help of a quadrate (0.25 x 0.25 m) placed randomly at two representative sites in each plot at 30 and 60 DAS. Weed samples were collected from the same area at 60 DAS for recording the total weed dry weight. Weed samples were sun dried before oven drying at 65 º C until constant weight was attained. The data on weed density and weed dry weight were subjected to square root transformation (x+0.5) to normalize their distribution. Weed control efficiency (WCE) was computed using the dry weight of weeds and weed index (WI) was computed using the grain yield of weed free check and yield of treated plot. Plant height and tillers per square meter were recorded at flowering stage and yield attributing characters like panicles per square meter, panicle weight, fertile grains per panicle and 1000 grain weight were recorded at harvest. Number of tillers and panicles were recorded by placing a quadrate (0.25 m x 0.25 m) at two spots in each plot. Plant height and yield attributing characters were recorded from 10 randomly selected hills. The grain yield was recorded at 13 per cent moisture. The data were analyzed separately for *kharif* 2011 and *rabi* 2011-12 using the ANOVA.

Results and Discussion

Weed flora

Weed density at 30 and 60 DAS indicated that major weed flora in the experimental field were; *Echinochloa stagnina* (Retz.) P. Beauv. (Hippo grass), *Echinochloa glabrescens* Munro ex Hook. f. (Barnyard grass) among grasses, *Fimbristylis miliacea* (L.) Vahl (Globe frigerush), *Cyperus difformis* L. (Umbrella sedge), *Cyperus iria* L. (Rice flat sedge), *Schenoplectus pungens* (Vahl) Palla (Three square Bulrush) among sedges, *Monochoria vaginalis* (Burm.f.) C. Presl. ex kunth (Pickerel weed), *Ludwigia perennis* L. (Water primrose) and *Sphenoclea zeylanica* Gaertner (Chickenspike) among broad

Table 1. Effect of weed control treatments on weed density, weed dry weight and weed control efficiency (kharif season, 2011)

Treatment	Weed density at 30 DAS (No./m_2)			Weed density at 60 DAS (No./ m_2)			Total weed dry weight at 60 DAS (g/m_2)	Weed control efficiency (%)
	Grasses	Sedges	BLW	Grasses	SedgesBLW			
Penoxsulam 24 SC at 25 g ai/ha on 15 to 20 DAS (T_1)	12.4	0	10.4	32.6	0	9.93	35.86	86.10
	(3.59)	(0.71)	(3.3)	(5.75)	(0.71)	(3.23)	(6.03)	
Pyrazosulfuron ethyl 10 WP at 20 g ai/ha on 4 to 7 DAS (T_2)	40.2	0	0	54.9	0	0	53.96	79.09
	(6.38)	(0.71)	(0.71)	(7.44)	(0.71)	(0.71)	(7.38)	
Bispyribac sodium 10 SC at 30 g ai/ha on 15 to 20 DAS (T_3)	5.3	3.42	0	11.12	1.09	0	7.28	97.18
	(2.4)	(1.98)	(0.71)	(3.41)	(1.26)	(0.71)	(2.79)	
Bensulfuron methyl + pretilachlor (6.6GR) at 0.06 +0.60 kg ai/ha on 8 to 10 DAS (T_4)	49.9	1.9	0	76.2	0	9.04	88.42	65.74
	(7.1)	(1.55)	(0.71)	(8.76)	(0.71)	(3.09)	(9.43)	
Weed free situation (T_5)	2.7	25	80.9	4.88	1.09	8.14	3.83	98.52
	(1.79)	(5.05)	(9.02)	(2.32)	(1.26)	(2.94)	(2.08)	
Hand weeding at 20 and 40 DAS (T_6)	6.4	28.9	87.9	4.93	1.09	11.54	5.21	97.98
	(2.63)	(5.42)	(9.4)	(2.33)	(1.26)	(3.47)	(2.39)	
Unweeded control (T_7)	114.9	29.8	99.9	144.70	24.5	67.56	258.07	
	(10.74)	(5.5)	(10.02)	(12.05)	(5.0)	(8.25)	(16.08)	
CD (P=0.05)	3.13	2.19	2.18	3.05	2.90	3.47	4.18	

Values in parenthesis are $\sqrt{x+0.5}$ transformed values

leaved weeds during both the seasons. Total weed density at 30 DAS comprised of grasses (46.98%), broad leaf weeds (40.84 %) and sedges 12.18%, respectively during *kharif* season and sedges (81.58 %), grassy weeds (14.03 %) and broad leaf weeds (4.39 %), respectively during *rabi* season. It was also observed that as the crop advanced its age there was decline in the total density of weeds (Table 1 and Table 2).

Table 2. Effect of weed control treatments on weed density, weed dry weight and weed control efficiency (*rabi season*, 2011)

Treatment	Weed density at 30 DAS (No./m_2)			Weed density at 60 DAS (No./m_2)			Total weed dry weight at 60 DAS	Weed control efficiency
	Grasses	Sedges	BLW	Grasses	Sedges	BLW	(g/m_2)	(%)
Penoxsulam 24 SC at 25 g ai/ha on 15 to 20 DAS (T_1)	3.42 (1.98)	0 (0.71)	0 (0.71)	0.89 (1.18)	0 (0.71)	1.60 (1.45)	0.26 (0.87)	99.57
Pyrazosulfuron ethyl 10 WP at 20 g ai/ha on 4 to 7 DAS (T_2)	2.22 (1.65)	0 (0.71)	0 (0.71)	2.22 (1.65)	0 (0.71)	0.89 (1.89)	0.52 (1.01)	99.13
Bispyribac sodium 10 SC at 30 g ai/ha on 15 to 20 DAS (T_3)	0 0.71)	0 (0.71)	0.89 (1.18)	4.79 (2.30)	14.48 (3.87)	4.79 (2.30)	1.06 (1.25)	98.23
Bensulfuron methyl + pretilachlor (6.6GR) at 0.06 +0.60 kg ai/ha on 8 to 10 DAS (T_4)	6.21 (2.59)	0 (0.71)	0 (0.71)	19.57 (4.48)	0 (0.71)	0.89 (1.18)	3.15 (1.91)	94.74
Weed free situation (T_5)	4.25 (2.18)	10.46 (3.31)	3.42 (1.98)	6.52 (2.65)	18.34 (4.34)	5.12 (2.37)	3.83 (2.08)	93.60
Hand weeding at 20 and 40 DAS (T_6)	0.89 (1.18)	475.61 (21.82)	26.02 (5.15)	0 (0.71)	56.65 (7.56)	41.62 (6.49)	13.26 (3.71)	77.85
Unweeded control (T_7)								
CD (P=0.05)	121.16 (11.03)	704.4 (26.55)	37.94 (6.20)	75.19 (8.70)	266.82 (16.35)	33.72 (5.85)	59.87 (7.77)	
	5.37	5.84	3.01	2.79	5.26	NS	2.24	

Values in parenthesis are $\sqrt{x+0.5}$ transformed values

Weed density

Weed control treatments showed significant reduction in the total density of sedges, grassy weeds and broad leaf weeds than weedy check (Table 1 and 2). All the tested herbicides showed significant reduction in the density of sedges and broad leaf weeds at 30 DAS compared to hand weeding twice at 20 and 40 DAS during both the seasons. This was mainly because of the escape or regeneration of weeds in manual weeding (Singh, 2008). Weed density at 30 DAS indicated that better control of sedges and broad leaf weeds were obtained by the early post emergence application of herbicides like pyrazosulfuron ethyl 10 WP at 20 g ai/ha and bensulfuron methyl + pretilachlor (6.6 GR) at 0.06 +0.6 kg ai/ha. Grassy weeds were effectively controlled by the post emergence application of bispyribac sodium 10 SC at 30 g ai/ha and penoxsulam 24 SC applied at 25 g ai/ha.

Weed density at 60 DAS indicated that both the early post emergence herbicides and penoxsulam 24 SC brought 100 per cent control of sedges during both the seasons. All the tested herbicides showed good control of broad leaf weeds compared to manual weeding. Pyrazosulfuron ethyl 10 WP applied on 4 to 7 DAS at 20 g ai/ha and bispyribac sodium10 SC applied on 15 to 20 DAS at 30 g ai/ha registered 100 per cent control of broad leaf weeds during *kharif* season. During *rabi* season pyrazosulfuron ethyl 10 WP and bensulfuron methyl + pretilachlor (6.6 GR) registered 97.36 per cent control of broad leaf weeds followed by penoxsulam and bispyribac sodium. The result is in conformity with the findings of Dixit and Varshney (2008), opined that early post emergence application of pyrazosulfuron ethyl was found promising for controlling broad leaved weeds and sedges in direct seeded rice.

Among the tested herbicides, bispyribac sodium registered lower density of grassy weeds (11.12 No./ m_2) during *kharif* season and proved superior over all other herbicide treatments. Being a member of pyrimidinyloxyl benzoic chemical family it inhibited acetolactate synthase enzyme in susceptible plants and retarding the synthesis of branch chain amino acids and killed the plant (Darren and Stephen, 2006). Penoxsulam was better in controlling grassy weeds than pyrazosulfuron ethyl. Among the herbicides, bensulfuron methyl + pretilachlor (6.6 GR) was The least effective in controlling grassy weeds (76.2 and 19.57 No./m_2) during both the seasons. This might be due its lesser efficacy in controlling grassy weeds (Table 1 and 2).

Weed dry weight and weed control efficiency

The weed dry weight was significantly influenced by the weed control treatments. The lowest weed dry weight (3.83 g/m_2) was recorded in weed free situation in *kharif* season and penoxsulam in *rabi* season (0.26 g/m_2). This was owing to the fact that penoxsulam registered lower density of broad leaf weeds and sedges than weed free situation in *rabi* season. Though the broadleaf weeds and sedges were effectively controlled by pyrazosulfuron ethyl, it recorded the weed dry weight of 53.96 g/m_2 in *kharif* season. This was mainly attributable to its lesser efficacy in controlling grassy weeds particularly *Echinochloa*. Similar findings were also observed by Subbaiah (2008) and Dixit and Varshney (2008). But in *rabi* season it recorded the weed dry weight of 0.52 g/m_2 due to the presence of lesser number of grassy weeds (Table 2). Among the tested herbicides, the highest dry weight was recorded in treatment T_4 (88.42 and 3.15 g/m_2) during *kharif* and *rabi* season.

Table 3. Effect of weed control measures on growth and yield attributes of direct seeded rice

Treatment	Plant height (cm)		Tillers/m_2		Panicles/m_2		Panicle weight(g)		1000 grain weight (g)	
	Kharif 2011	*rabi* 2011	*kharif* 2011	*rabi* 2011	*kharif* 2011	*rabi* 2011	*kharif* 2011	*rabi* 2011	*kharif* 2011	*rabi* 2011
Penoxsulam 24 SC at 25 g ai/ha on 15 to 20 DAS (T_1)	85.6	72.37	291	359	284	359	3.2	2.3	23.70	22.73
Pyrazosulfuron ethyl 10 WP at 20 g ai/ha on 4 to 7 DAS (T_2)	90.2	70.26	269	369	263	363	4.1	2.2	23.33	23.43
Bispyribac sodium 10 SC at 30 g ai/ha on 15 to 20 DAS (T_3)	89.1	70.10	297	354	293	352	3.0	2.1	23.40	23.90
Bensulfuron methyl + Pretilachlor (6.6 GR) at 0.06 +0.60 kg ai/ha on 8 to 10 DAS (T_4)	85.4	68.63	223	345	215	341	3.1	2.0	22.77	22.97
Weed free situation (T_5)	93.4	67.95	334	445	329	443	2.8	2.6	23.87	22.77
Hand weeding at 20 and 40 DAS (T_6)	90.2	71.64	291	415	283	411	3.4	2.2	23.90	22.80
Unweeded control (T_7)	74.4	65.29	181	179	178	179	2.2	1.8	21.50	20.63
CD (P=0.05)	NS	NS	18	52	33	41	0.8	0.4	0.79	0.75

This was due to its lesser efficacy in controlling *Echinochloa* causes the increase in weed dry weight (Table 1 and 2).

Among the herbicide treatments, the maximum weed control efficiency (97.18 %) was recorded in plots treated with bispyribac sodium 10 SC during *kharif* season followed by penoxsulam 24 SC (86.10 %)). This might be due to the better control of weeds resulting in minimum weed biomass production. But in *rabi* season the maximum weed control efficiency was recorded in penoxsulam treated plots (99.57 %) followed by pyrazosulfuron ethyl (99.13 %). This was owing to the fact that during *rabi* season sedges population more and penoxsulam and pyrazosulfuron ethyl had a better control of sedges than bispyribac sodium (Table 1 and 2). The lowest weed control efficiency of 65.74 per cent was recorded in crop treated with bensulfuron methyl + pretilachlor (6.6 GR) in *kharif* season. This was due to its poor efficacy of controlling grassy weeds particularly *Echinochloa* resulting in increased weed biomass. But in *rabi* season, it recorded the weed control efficiency of 94.74 per cent due to the better control of sedges and broad leaf weeds predominant during the season.

Crop growth and yield attributes

Weed control treatments brought out significant effect on growth and yield attributes as compared to weedy check (Table 3). There was no significant difference in plant height was observed among the treatments. The weed free situation recorded plants with maximum height in *kharif* season (93.43cm) and penoxsulam treated plots in *rabi* season (72.37) and tillers per meter square was found to be more in weed free situation in both seasons. Among the herbicide treatments, bispyribac sodium applied at 30 g ai/ha at 15 to 20 DAS recorded maximum tillers per square meter in *kharif* season and pyrazosulfuron ethyl applied at 20 g ai/ha on 4 to7 DAS in *rabi* season. This was due to better growth of plants on account of reduced crop -weed competition at critical stages of crop growth resulting in increased availability of nutrients, water, space and light. The highest number of panicles per square meter was observed in weed free situation. Among the tested herbicides, higher number of panicles was observed in bispyribac sodium treated plots and it was on par with penoxsulam and pyrazosulfuron ethyl during *kharif* season. In *rabi* season, the highest number was observed in pyrazosulfuron ethyl treated plots

followed by penoxsulam and bispyribac sodium. The percentage reduction in panicles per square meter in T_3, T_1, T_2 and T_4 compared to T_5 were in order of 10.94 per cent, 13.68 per cent, 20.06 per cent, and 34.65 per cent, respectively in *kharif* season. But in *rabi* season the percentage reduction was in the order of 20.54 per cent, 19.19 per cent, 18.28 per cent and 23.02 per cent, respectively. Difference in percentage reduction in panicles in these treatments might be due to the difference in the effectiveness of herbicides to control the different group of predominant weeds as evident from the data on weed density and weed dry weight.

Table 4. Effect of weed control treatments on grain yield and weed index (*kharif and rabi season*)

Treatment	Grain yield (kg/ha)		Weed index	
	kharif 2011	*rabi* 2011	*kharif* 2011	*rabi* 2011
Penoxsulam 24 SC at 25 g ai/ha on 15 to 20 DAS (T_1)	4784	3678	19.54	7.61
Pyrazosulfuron ethyl 10 WP at 20 g ai/ha on 4 to 7 DAS (T_2)	4226	3914	28.93	1.69
Bispyribac sodium 10 SC at 30 g ai/ha on 15 to 20 DAS (T_3)	4898	3649	17.63	8.34
Bensulfuron methyl + pretilachlor (6.6 GR) at 0.06 + 0.6 kg ai/ha on 8 to 10 DAS (T_4)	3018	3472	49.24	12.79
Weed free situation (T_5)	5946	3981	-	-
Hand weeding at 20 and 40 DAS (T_6)	5070	3821	14.73	4.02
Unweeded control (T_7)	1801	1298	69.71	67.40
CD (P=0.05)	834	509		

Results also indicated that among the herbicides, pyrazosulfuron ethyl treated plots recorded panicles with maximum filled grains in both the seasons. Significantly lower values of panicles per square meter, filled grains per panicle and panicle weight were recorded under unweeded control. The result is in conformity with the finding of Gopinath and Kundu, (2008) and Khaliq *et al*. (2011.)

Grain yield and weed index

Weed control treatments significantly influenced the grain yield of direct seeded rice. Adoption of different weed management measures enhanced the grain yield from 1801 kg/ha to 5946 kg/ha in *kharif* season and from 1298 kg/ha to 3981 kg/ha in *rabi* season . The increase ranged from 40.32 to 69.71 per cent and 62.62 per cent to 67.40 per cent, respectively over unweeded control in *kharif* season and *rabi* season (Table 4).

Weed free situation registered the highest grain yield in both the seasons (Table 4). Among the herbicides, bispyribac sodium10 SC applied at 30 g ai/ha on 15 to 20 DAS registered the highest grain yield (4898 kg/ha) which was on par with penoxsulam applied at 25 g ai/ha (4784 kg/ha) on 15 to 20 DAS and pyrazosulfuron ethyl 10 WP applied at 20 g ai/ ha (4226 kg/ha) on 4 to 7 DAS in *kharif* season. In *rabi* season pyrazosulfuron ethyl (3914 kg/ha) recorded the highest grain yield which was on par with penoxsulam (3678 kg/ha) and bispyribac sodium (3649 kg/ha). During *kharif* season the lowest weed index was recorded in hand weeding twice at 20 and 40 DAS (14.73 %) followed by bispyribac sodium (17.63 %), penoxsulam (19.54 %) and pyrazosulfuron ethyl (28.93 %). In *rabi* season the lowest weed index was recorded in pyrazosulfuron ethyl (1.69 %) followed by hand weeding twice at 20 and 40 DAS (4.02 %), penoxsulam (7.61 %) and bispyribac sodium (8.34 %). During both the seasons the highest weed index and lowest grain yield were observed in bensulfuron methyl + pretilachlor (6.6 GR) applied at (0.06 +0.60 kg ai/ha) on 8 to 10 DAS. This might be due to its lesser efficacy in controlling grassy weeds particularly *Echinochloa* at critical stages of crop growth causes greater competition for space nutrients and light and resulted in lesser number of panicles per square meter (Table 3). Unweeded control recorded 69.71 per cent lesser yield in *kharif* season and 67.40 per cent lesser yield in *rabi* season due to very severe weed competition and improper utilization of nutrient, space and light. The result is in conformity with the findings of Mohan *et al*. (2010) and Kachroo and Bayaza (2011).

It is concluded from the study that predominance of weed flora was influenced by the season of cultivation. During *kharif* season the weed flora was dominated by grasses and during *rabi* season the weed flora was dominated by sedges. Post emergence application of bispyribac sodium10 SC at 30 g ai/ha and penoxsulam 24 SC at 25 g ai/ha (15 to 20 DAS) and early post emergence application of pyrazosulfuron 10 WP at 20 g ai/ ha (4 to 7 DAS) were found effective for the broad spectrum control of weeds in direct seeded rice under puddled condition. Based on the overall rice yield across herbicide treatments, bispyribac sodium 10 SC at 30 g ai/ha, penoxsulam 24 SC at 25 g ai/ha and pyrazosulfuron ethyl 10 WP at 20 g ai/ha were comparable during both the seasons. Hence these chemicals can be recommended for weed control and higher productivity in direct seeded rice under puddled irrigated conditions of Kuttanad.

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