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Effect of weed control methods on yield and yield attributes of soybean

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Two field experiments were conducted at the experimental farm of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus in the kharif seasons of 2004 and 2005 to study the effect of various weed control methods on yield and yield attributes of soybean. All weed control measures registered significantly higher seed yields of soybean than weedy check. However, weed free treatments, hand weeding twice and both fluchloralin and pendimethalin integrated with hand weeding recorded far superior yields of soybean seed. Integrated use of herbicides gave better seed yield than their individual application. Similarly, higher doses of both herbicides gave more yield than their lower doses. Pendimethalin 1.5 kg ha^{-1} and hand weeding once recorded comparable yields of soybean. Seed protein content was significantly greater under all weed control measures. Weed free treatment, hand weeding twice and pendimethalin integrated with hand weeding recorded comparable percentage of both these parameters; while, in case of oil content, hand weeding twice, higher dose of pendimethalin and both the herbicides at low rates, integrated with hand weeding recorded comparable oil content in soybean seed. Fluchloralin and pendimethalin at either of the two rates namely 1.0 and 1.5 kg ha^{-1} gave statistically similar values of oil content as that recorded by hand weeding once. Lowest oil percentage was seen in the weedy check plots.

Key words: treatments, fluchloralin, pendimethalin, weed, soybean.

INTRODUCTION

Soybean [*Glycine max* (L.) Merill] popular as golden bean has become the miracle crop of 21st century. It serves the dual purpose for being grown both as an oilseed crop and pulse crop as well (Thakare et al., 2006). It is an excellent health food containing 40 to 44% good quality protein, 20% cholesterol free oil, 20% carbohydrates and 0.69% phosphorus. It also fixes atmospheric nitrogen (45 to 60 kg ha^{-1}) through root nodules and adds about 0.5 to 1.5 ton organic matter per hectare through leaf fall (Kanase et al., 2006). Reduction in soybean yield due to weed infestation varies from 27 to 77% (Gogoi et al., 1991), depending on type of weed, soil, seasons and weed infestation intensities. Some have reported the yield decline as high as 84% (Kachroo et al., 2003). Weed infestation removed 21.4 kg N and 3.4 kg P ha^{-1} in soybean (Pandya et al., 2005). Two hand hoeings are recommended for effective weed control in soybean (Jain, 2000; Rakesh and Shirvastava, 2002; Galal, 2003; Singh and Jolly, 2004). Ahmed et al. (2001) reported that application of two hand hoeings is more effective in suppressing weeds and increasing soybean seed yield. Today, there is a great manual labor shortage and a rise in wage scale. Thus, chemical weed control is necessary to decrease cost and to increase soybean productivity. This crop is a large herbicide consumer, and almost 90% of the planted area in India is herbicide-treated. The advantages of herbicide use are high efficiency in weed control, the presence of selective products soybean at

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Table 1. Weed flora of the experimental field.

Scientific name	Common name	Kashmiri name
Broad leaf weeds		
Amaranthus spp.	Pig weed	Lisa
Chenopodium album L.	Common lambsquarters	Kon'e/von palak
Convolvulus arvensis L.	Bind weed	Thrir
Portulaca oleracea L.	Purselane	Nuner
Capsella bursa-pastoris L.	Shepherd's purse	Kralmund
Solanum nigram L.	Black night shade	Kambal
Grassy weeds		
Cynodon dactylon	Bermuda grass	Dramun
Echinochloa colonum	Jungli rice	Hama
Poa annua	Blue grass	Mahigase
Sedges		
Cyperus rotundus	Nut sedge	Mothe

the lowest cost, compared to other available weed control methods. Despite the satisfactory weed control results, many questions remain on the effect of herbicides on the N_2 fixation process, since the soybean crop is dependent on symbiosis with bradyrhizobium (Zawoznik et al., 1995).

Pre-emergence herbicide application can help control weeds, to some extent, during the early crop growth stage. Soybean undergoes heavy weed competition especially in the early growth stages. Crop-weed competition is minimized by pre-emergence herbicide spray, resulting in decreasing weed dry matter and increasing crop yield (Jeyabal et al., 2001; Mohamed, 2004; Sha, 2004). Regarding chemical weed control, selective herbicides may be effective against annual weeds and achieve high soybean and legume yield such as butralin (Hassanein, 2000; El-Metwally and Saad El-Din, 2003), prometryn (Sha, 2004; Abd El-Razik, 2006) and oxadiargyl (Dobrzanski et al., 2001). Hence, two field experiments were conducted to examine the effects of different herbicides, applied at pre-emergence on weed infestation, yield and yield attributes of soybean plants.

MATERIALS AND METHODS

Two field experiments were conducted at the experimental farm of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus in the kharif seasons of 2004 and 2005. The soil of the experimental field was silty clay loam with normal pH and EC, high in organic carbon, medium in nitrogen and potash and low in phosphorous. The experiment was laid out in a split pot design with 10 treatments and three replications. The treatments consisted of weedy check, eight weed control methods namely; 1 hand weeding (HW) 25DAS, 2 HW 25 and 45 DAS, pre-plant incorporation of fluchloralin 1.0 and 1.5 kg a.i ha^{-1} pre-plant incorporation of flucholarin 1.0 kg a.i + 1 HW 35 DAS, pre-emergence application of pendimethalin 1.0 kg a.i ha^{-1} + 1 HW 35 DAS and weed free treatment obtained by continuous hand weeding. After application of the pre-emergence herbicides, all the experimental plots were irrigated. When soil moisture became adequate (3 to 4 days later), the seeds of soybean (*Glycine max*) cv. 'PS-1092' were sown on hill 20 cm apart in both sides of the ridge. The crop was sown on 23rd May during both 2004 and 2005. After complete germination, soybean seedlings were thinned to secure two plants per hill. The first irrigation was carried out 40 days after sowing. Fertilizers N, P and K were applied during soil preparation and before sowing. All recommended agricultural practices were adopted throughout the two seasons.

After maturity, soybean plants were harvested to estimate number of pods per plant, pod weight per plant (g), number of seeds per plant, seed yield per plant (g), seed yield (kg ha^{-1}), biological yield per plant (g) and 100-seed weight (g). The seeds were ground to pass a 0.5 mm sieve to estimate N and oil contents. Total nitrogen content of the seeds was determined according to AOAC (1980). N values were multiplied by 6.25 to calculate total crude protein (TCP). The oil content was determined with the help of nuclear magnetic resonance (NMR) spectroscopy technique (Alexander et al., 1967) for each representative sample. The oil content was worked out as the following and expressed as percent. The data recorded for different parameters were subjected to statistical analysis as per the method of analysis of variance as suggested by Gomez and Gomez (1984). Wherever, the 'F' test was found significant at 5% probability, the critical difference value was used to compare the treatment means and their interaction effects wherever required data was subjected to square root $\sqrt{x+0.5}$ transformation. The software used for this analysis was $CPCS_1$.

RESULTS AND DISCUSSION

Weed species

Major weed floras found in the experimental field were grouped into broad leaf weeds, grassy weeds and sedges (Table 1 and Plate 1). The physiological and yield responses of soybean to an herbicide may vary, and may also depend on geographical location, environmental conditions, soil types, sensitivity of native populations of *Bradyrhizobium japonicum* etc. (Zablotowicz and Reddy, 2007). Significant differences were observed in function of weed management practices in yield and its attributes

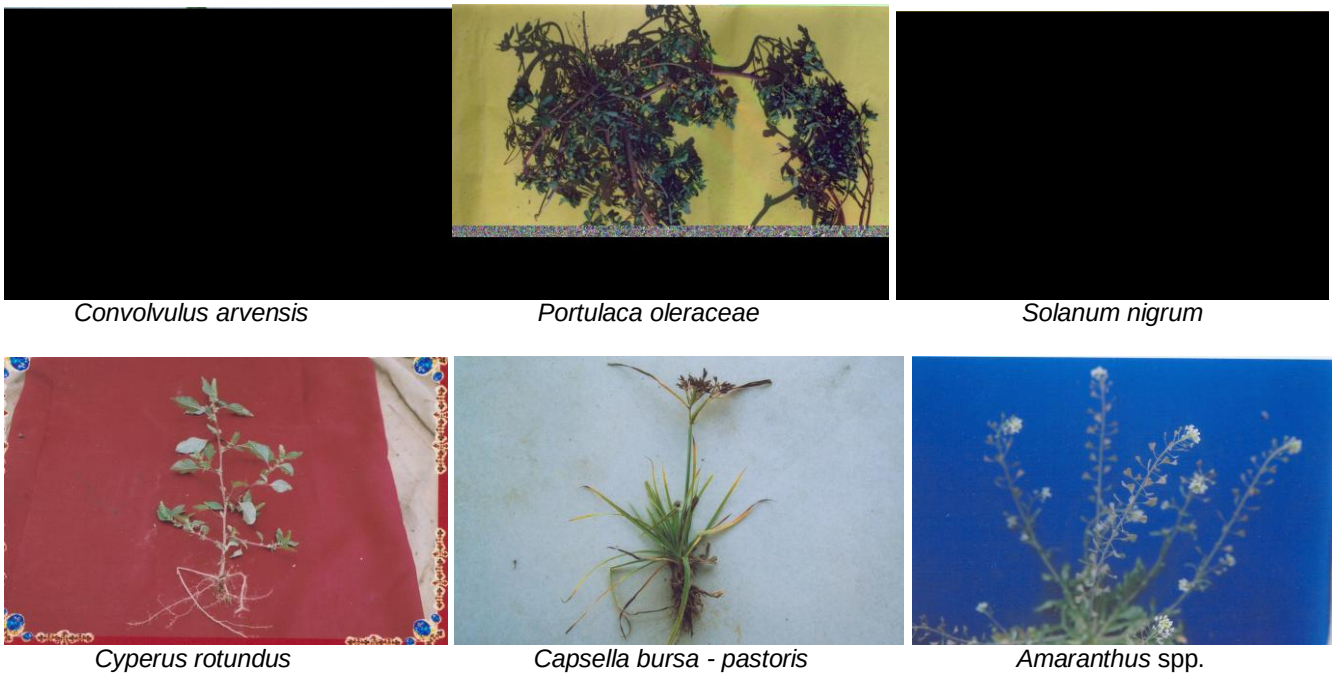

Plate 1. Soybean yield and yield components.

(Tables 2 and 3). Greater weed competition in weedy check resulted in reduced number of branches per plant under this treatment at harvest. Consequently, weed control measures offered a better environment for enhanced branching by crop. Significantly, highest number of branches was recorded in weed free plots comparable with twice hand weeding treatments. Herbicides proved more effective at higher rates when applied alone. However, when combined with one hand weeding, they were more effective. Increased number of branches as a result of chemical and hand weeding methods has also been reported by Kushwah and Vyas (2005). Various yield components were markedly influenced by different weed control measures. Maximum number of pods was produced by weed free treatments (W_{10}) which was at par with hand weeding twice (W_3). Other weed control treatments also affected significantly higher number of pods as compared to un-weeded control (W_1) which gave the lowest number of pods per plant.

Severe weed competition in the weedy check might have reduced the number of pods per plant. Weed free treatment produced 60.08 and 56.67% extra pods than control. Jain (2000) also got highest pods in weed free treatment. Fluchloralin and pendimethalin at lower rates (1 kg ha^{-1} each) when integrated with hand weeding resulted in greater values of pods per plant than when applied alone recording at par influence with weed free in 2005. This is clearly indicative of more pronounced affect of their integrated use because of the fact that initial achievement of limiting weed growth by the herbicides is maintained as hand weeding eliminates the fresh flush of weeds that may regenerate due to loss of persistence of the applied herbicides as in the case of herbicides applied alone. A number of researchers like Veeramani et al. (2001) held similar views and reported more pods with integrated use of herbicides with hand weeding. Herbicides applied alone recorded pods at par with hand weeding once at 25 DAS. Number of pods per unit area basis was significantly influenced by different weed control measures. Weed free treatment (W_{10}) and hand weeding twice (W_3) affected number of pods per square metre that were at par with each other. Herbicides applied individually and in integration with one hand weeding at 35 DAS also caused significant enhancement in the number of pods per square metre as compared to un-weeded control. Both the number of seeds per pod and 100-seed weight were benefited by various weed control measures.

Weed free treatment (W_{10}) and hand weeding twice (W_3) were at par with each other in producing significantly highest number of seed per pod and also affecting highest 100-seed weight. Un-checked growth of weeds in weedy check caused lowest number of seeds per pod and 100-seed weight. Hand weeding twice (W_3) was found statistically at par with fluchloralin 1 kg integrated with hand weeding (W_8) and pendimethalin 1 kg integrated with hand weeding (W_9) with respect to the number of seeds per pods and 100-seed weight. Herbicides applied alone too had a significant promising influence on test weight giving higher values than the weedy check. Reduced weed competition as a

Table 2. Yield attributes of soybean as influenced by weed control methods.

Treatments	Branches per plant		Pods/plant (no.)		Pods/square metre (no.)		Seeds/pod (no.)		100-seed weight (g)		Biological yield (g)		Harvest index (%)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
W_1	6.57	7.74	42.49	44.70	756.33	793.66	1.80	1.82	10.015	10.100	47.25	46.96	34.52	34.25
W_2	8.60	8.84	50.80	53.59	1086.08	1053.55	2.10	2.15	10.797	10.930	58.28	59.43	35.08	35.00
W_3	9.30	10.07	58.07	61.87	1161.55	1182.66	2.32	2.40	11.224	11.617	67.07	67.75	36.01	36.07
W_4	7.80	8.23	51.43	50.14	965.00	999.33	2.03	1.98	10.745	10.910	54.46	56.55	34.12	33.60
W_5	8.00	7.69	45.75	49.37	1002.11	952.88	1.91	1.99	10.822	11.020	56.75	58.33	34.88	34.48
W_6	8.30	8.75	46.81	49.72	926.88	958.41	2.04	1.87	10.693	10.961	55.43	55.74	35.24	35.88
W_7	8.73	8.32	50.71	52.86	948.33	1013.84	2.06	2.00	10.953	10.980	57.74	59.46	35.89	35.45
W_8	8.70	8.90	56.75	63.68	1052.12	1139.56	2.18	2.26	11.050	11.313	62.72	61.86	35.22	35.30
W_9	9.07	9.36	59.90	64.64	1085.34	1129.17	2.29	2.18	11.174	11.200	65.07	66.56	36.03	36.11
W_{10}	10.02	10.80	68.02	70.03	1174.21	1212.89	2.52	2.80	11.08	12.05	69.29	70.60	36.19	36.26
SE m±	0.27	0.35	2.27	3.06	20.87	23.69	0.07	0.08	0.242	0.259	0.33	0.33	0.31	0.34
CD (P = 0.05)	0.77	0.99	6.41	8.65	60.11	68.24	0.20	0.22	0.678	0.737	0.93	0.94	0.90	0.95

Where W_1 (weedy check), W_2 (1 HW 25 DAS), W_3 (2 HW 25 and 45 DAS), W_4 (fluchloralin 1 kg ha^{-1}), W_5 (fluchloralin 1.5 kg ha^{-1}), W_6 (pendimethalin 1 kg ha^{-1}) , W_7 (pendimethalin 1.5 kg ha^{-1}), W_8 (fluchloralin 1 kg ha^{-1} + 1 HW 35 DAS), W_9 (pendimethalin 1 kg ha^{-1} + 1 HW 35 DAS), W_{10} (weed free).

consequence of weed control measures enabled to affect improved 100-seed weight in soybean possibly due to enhanced availability of nutrients etc. The results are akin to those reported by Vyas and Jain (2003). Severe weed competition due to unchecked weed growth and consequent reduction in seeds per pod and test weight was also observed by Rathman and Miller (1981). Seed yield is the most important criterion and the ultimate test to estimate and compare the efficiency of a particular treatment. As such, this parameter needs a thorough and comprehensive discussion here.

All weed control measures gave significantly higher seed yields than weedy check (Table 3). However, weed free treatment (W_{10}), hand weeding twice (W_3) and fluchloralin and pendimethalin 1 kg ha^{-1} integrated with hand weeding once (W_8 and W_9) procured far superior seed yields of soybean. The increase in seed yield due to these treatments on pooled basis was to the tune of 59.81, 53.25, 38.42 and 49.78%, respectively. Pendimethalin when applied alone or integrated with hand weeding was more effective than similar application of fluchloralin. Integrated use of both fluchloralin and pendimethalin with hand weeding yielded 4.72 and 8.21%, respectively more than their individual application. Higher doses (1.5 kg ha^{-1}) of herbicides proved more effective and produced superior seed yields than their lower doses (1.0 kg ha^{-1}), the increase being 6.34 and 5.98% for fluchloralin and pendimethalin, respectively. The yield given by pendimethalin 1.5 kg ha^{-1} (W_7) was comparable to that produced by hand weeding once (W_2) in both the years. The enhancement in the seed yield due to various weed control measures was because of the fact that they helped to keep the field comparatively free from weeds, thus resulting in better utilization of resources namely, nutrients, moisture, solar light etc. This consequently led to the production of more vigorous and healthy plants having more pod bearing capacity, more seed per pod and 100-seed weight. The cumulative effect of all these resulted in higher seed yields, making it amply clear that these weed control measures exerted a profound influence in curtailing the weed population and thereby reducing the weed biomass at important growth stages of the crop.

The results corroborate the findings of Vyas et al. (2000) and Pandya et al. (2005) and many others who reported enhanced soybean yield due to various weed control treatments. Weedy check produced lowest yield of soybean which was significantly inferior to different weed control treatments. Drastic yield reduction in weedy check

Table 3. Seed yield and straw yield of soybean as influenced by weed control methods.

Treatment	Seed yield (q/ha)		Pooled	Straw yield	
	2004	2005		2004	2005
W_1 (Weedy check)	15.97	15.74	15.85	30.28	30.20
W_2 (1 HW 25 DAS)	20.91	21.20	21.05	37.37	38.23
W_3 (2 HW 25 and 45 DAS)	24.10	24.44	24.29	42.42	43.31
W_4 (fluchloralin 1 kg ha^{-1})	18.58	19.00	18.76	35.88	37.35
W_5 (fluchloralin 1.5 kg ha^{-1})	19.80	20.11	19.95	36.95	38.22
W_6 (pendimethalin 1 kg ha^{-1})	19.52	20.00	19.72	35.86	35.73
W_7 (pendimethalin 1.5 kg ha^{-1})	20.73	21.07	20.90	37.00	38.09
W_8 (fluchloralin 1 kg ha^{-1} + 1 HW 35 DAS)	22.10	21.79	21.94	40.62	40.08
W_9 (pendimethalin 1 kg ha^{-1} + 1 HW 35 DAS)	23.45	24.04	23.74	41.57	42.49
W_{10} (weed free)	25.08	25.60	25.33	44.21	45.00
SE m±	0.23	0.29	0.25	0.25	0.26
CD (P = 0.05)	0.66	0.81	0.70	0.71	0.75

was due to heavy infestation of weeds, especially broad leaved weeds which grow faster and suppressed the crop growth, thus causing reduced yields. The broad leaved weeds on an average contributed 62.65% of total weed population. Howe and Oliver (1987) also reported reduced yield in weedy check due to higher density of weeds especially broad leaved weeds. The straw yield depicted a trend similar to seed yield. Significantly, superior straw yield was seen in different weed control treatment especially weed free treatment (W_{10}), hand weeding twice (W_3) and fluchloralin and pendimethalin (each 1 kg ha^{-1}) integrated with hand weeding (W_8 and W_9). Biological yield was favourably influenced by various weed control treatments. Weed free plots (W_{10}), hand weeding twice (W_3), fluchloralin and pendimethalin 1 kg/ha integrated with hand weeding (W_8 and W_9) far excelled in their influence in recording higher biological yield over weedy check and produced 51.76, 46.20, 35.12 and 43.06% more biological yield than un-weed control. Herbicides applied alone under different concentrations (W_4, W_5, W_6, W_7) too were efficient in producing higher biological yields, however, the treatments lagged behind hand weeding once (W_2) except pendimethalin 1.5 kg ha^{-1} with which it was comparable. Harvest index of soybean exhibited pronounced influence of various weed control treatments. Weed free treatment (W_{10}), hand weeding twice (W_3) and pendimethalin 1 kg ha^{-1} in integration with hand weeding once (W_9) produced statistically similar harvest index. Weedy check (W_1) affected significantly least harvest index compared to all the weed control treatments. The higher doses of both fluchloralin and pendimethalin (W_5 and W_7) proved significantly more effective than their corresponding low doses (W_4 and W_6). This was possibly due to persistence of these herbicides for longer duration at the higher concentration compared to their lower ones. Bhandiwaddar and Itnal (1998) also reported superiority of various weed control methods with respect to harvest index of soybean over unweeded control.

Seed composition

Seed protein content of soybean was favourably and significantly influenced by different weed control treatments (Table 4). Weed free (W_{10}) and hand weeding twice (W_3) exhibited statistically similar protein content. Hand weeding twice (W_3) was also comparable to pendimethalin 1 kg/ha integrated with hand weeding once (W_9) with respect to protein content but superior to rest of the treatments besides the weedy check. Fluchloralin and pendimethalin (1 kg/ha each) supplemented with hand weeding (W_8 and W_9) were at par with each other for protein content. On an average, 14.04, 12.54 and 11.37% more protein content in seed was affected by weed free treatment, hand weeding twice and pendimethalin 1 kg ha^{-1} integrated with hand weeding once over that given by weedy check. The better protein content in soybean crop as a result of weed control measures could be attributed to better nitrogen content under these treatments favoured by effective elimination of weeds. Presence of weeds throughout the growing season in weedy check plots was instrumental in reduced protein content in these plots. The results corroborate the findings of Mohamed (2004) and EL-Metwally and Shalby (2007). So for as the oil content is concerned, hand weeding twice (W_3), higher dose of pendimethalin (1.5 kg/ha) (W_7) and both fluchloralin and pendimethalin 1 kg/ha supplemented with hand weeding (W_8 and W_9) recorded comparable oil content in soybean seed in both years. Both fluchloralin and pendimethalin at either of two rates namely, 1.0 and 1.5 kg ha^{-1} gave oil content that was at par with hand weeding once. Although, hand weeding twice was statistically similar to hand weeding once in 2004 with respect to oil content, it produced a significant improvement in this important quality

Table 4. Oil content (%) and crude protein content (%) of soybean as influenced by weed control.

Treatment	Oil content (%)		Crude protein content (%)	
	2004	2005	2004	2005
W_1 (Weedy check)	17.81	18.05	36.57	35.68
W_2 (1 HW 25 DAS)	19.07	19.00	38.19	38.66
W_3 (2 HW 25 and 45 DAS)	19.97	19.88	39.94	41.36
W_4 (fluchloralin 1 kg ha^{-1})	18.67	19.00	38.14	37.46
W_5 (fluchloralin 1.5 kg ha^{-1})	18.93	19.03	38.30	37.50
W_6 (pendimethalin 1 kg ha^{-1})	18.98	18.84	38.24	38.12
W_7 (pendimethalin 1.5 kg ha^{-1})	19.09	19.28	38.55	39.12
W_8 (fluchloralin 1 kg ha^{-1} + 1 HW 35 DAS)	19.28	19.48	39.09	40.00
W_9 (pendimethalin 1 kg ha^{-1} + 1 HW 35 DAS)	19.35	19.73	39.78	40.68
W_{10} (weed free)	19.69	20.19	40.62	41.76
SE m±	0.45	0.36	0.42	0.60
CD (P = 0.05)	0.92	0.72	0.84	1.22

parameter in 2005.

Weedy check proved very poor exhibiting significantly inferior values of oil content in soybean seed which was 10.82 and 9.12% deficit as compared to hand weeding twice in 2004 and 2005, respectively. Enhancement in the oil content of soybean as affected by various weed control measures may be attributed to better nutrition of the soybean which play a vital role in improving oil value of soybean. Increased oil content in soybean under weed control treatments has also been reported by Mohamed (2004) and EL-Metwally and Shalby (2007).

Conclusion

Pendimethalin 1.0 kg ha^{-1} integrated with one hand weeding at 35 DAS (critical period of weed removal) is the most appropriate method for effective weed management and profitable cultivation of soybean. Other methods are either less profit earners or are labour expensive.

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