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IMPACT OF RATE AND TIMING OF NITROGEN APPLICATION ON YIELD AND QUALITY OF CANOLA (*BRASSICA NAPUS* L.)

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Abstract

Canola crop is substituting the indigenous rape and mustard crops due to its high quality edible oil and to its ability to grow well on rain and canal irrigated areas. Nitrogen is one of the most important nutrients for growth and development. A two-years field study (Nov. 2001-April 2003) was carried out to determine optimum N level and stage of its application for canola crop under irrigated conditions of Faisalabad, Pakistan. Five N levels (0, 30, 60, 90 and 120 kg ha^{-1}) were maintained at different times i.e., full N at sowing, ½ N at sowing +½ N at branching, ½ N at sowing + ½ N at flowering and ½ N at branching + ½ N at flowering. The total dry matter (TDM), crop growth rate (CGR), leaf area duration (LAD), seed yield, oil yield and protein content were significantly affected by different nitrogen rates. The highest N level (120 kg ha^{-1}) produced maximum values for all these traits as compared to minimum in control during both years of study. Time of nitrogen application did not significantly affect TDM, CGR, protein and oil contents however, split application of nitrogen (½ at sowing + ½ at branching or flowering) produced significantly higher seed and oil yield than full nitrogen at sowing or its split application as ½ at branching + ½ at flowering.

Introduction

Pakistan is deficit in edible oil production. The consumer's demand has steadily increased from 0.3 million tons to 2.764 tons during the last two and half decades with almost stagnant domestic production of 0.857 million tons. At present indigenous oil seed production meets only 27% of domestic requirement, while the remaining 73% is met through imports. During 2008-09 (July-March), 1.29 million tones edible oil costing Rs. 84 billion were imported (Anon., 2009). To narrow down this gap concrete efforts are needed to increase its local production.

Traditional brassica species like Indian colza (sarson), Indian mustard (raya) and rochet (taramira) are being grown successfully on marginal lands and barani areas which can easily be replaced by canola as its production potential is higher than other rapeseed and mustard. Substitution of indigenous rape seed and mustards with that of canola by adopting improved production technology can increase the production of edible oil. Canola is a newly emerging rape seed crop replacing sarson (Tahir *et al*., 2007) due to its low erucic acid (<2%) and low glucosinolate (<30 µg g^{-1}) which is fit for human being and livestock as well.

National average yield of canola is 1279 kg ha^{-1} (Anon., 2009) which is far below the potential of most of the cultivars. Newly evolved canola varieties have made possible to switch over the area previously under traditional *Brassica* species to canola but information regarding its optimal agro-management requirements for realizing a good harvest under different agro-environmental conditions is very meager.

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One of the main causes of low yield is imbalanced and inadequate supply of nutrients. Amongst the other major nutrients nitrogen plays an important role in the growth and development of canola plant. Higher N application rates led to rapid leaf area development, prolonged the life of leaves, improved leaf area duration, increased overall crop assimilation and thus contributing to increased seed yield (Wright *et al*., 1988). Oil contents per unit seed weight decreased with increasing rate of N application (Yusuf & Bullock, 1993). While comparing different nitrogen rates (30, 60, 90, 120 and 180 kg ha^{-1}), Velichka *et al*., (1998) recorded highest seed yield of rape with 180 kg N ha^{-1}, with oil content decreasing by 1.97%. In a study conducted by Jasinska *et al*., (1997) seed yield and protein content in rape increased with increasing nitrogen rate from 40 to 160 kg ha^{-1}, however seed oil content was not affected by nitrogen rate. Nitrogen application as split dose (half at sowing plus half with first irrigation) increased seed yield and biomass accumulation of rapeseed (Tamagno *et al*., 1999) than when applied in a single dressing, further splitting the top dressing did not significantly increase yield (Wojnowska *et al*., 1995). Keeping this in view, the present studies were carried out with the hypothesis that the application of nitrogen in proper amount and at proper crop growth stage will improve growth, yield and quality of produce of canola under agro-ecological conditions of Faisalabad.

Materials and Methods

Studies were conducted at the Agronomic Research Area ($31^0$25' N, $73^0$09' E), Department of Agronomy, University of Agriculture Faisalabad during 2001-02 and 2002-03, in randomized complete block design (RCBD) with split plot arrangement. The experiment was replicated thrice with a net plot size of 2.7 m x 5 m. Four levels of nitrogen i.e., N_0 (control, without N), N_1 (30), N_2 (60), N_3 (90) and N_4 (120) kg N ha^{-1} were kept in main plots which were applied at four different crop stages i.e., T_1 (Full N at sowing), T_2 (½ N at sowing + ½ N at branching), T_3 (½ N at sowing + ½ N at flowering), T_3 (½ N at sowing + ½ N at flowering) and T_4 (½ N at branching + ½ N at flowering) in sub- plots. Phosphorus as Diammonium phosphate was applied @ 60 kg P_2O_5 ha^{-1} before sowing. Canola variety “Zafar- 2000” was sown on 3rd October 2001 and 6th October 2002, respectively using seed rate of 5 kg ha^{-1}. Sowing was carried out in rows maintaining row to row distance of 30 cm with single row hand drill on a well-prepared fine seedbed. Three irrigations were applied to each plot during the growth period of the crop; first irrigation was given at branching, second at flowering and third at pod formation. Thinning was done twice; first at two and second at four leaf stage, to maintain optimum plant population.

Hoeing was done to keep the crop weed free and insecticide Methamidophos @ 1 L ha^{-1} was sprayed twice to control aphid at siliquae development stage. All other agronomic practices were kept uniform and normal for all the treatments. The crop was harvested manually when 60 % siliquae turned brown on 18th and 23rd April in 2002 and 2003, respectively. Crop was threshed manually; seed obtained from each plot were weighed separately and then converted into seed yield in kg ha^{-1}. Oil content of seed was estimated by the NMR test (Robertson & Morrison, 1979)

For this purpose seed samples from each plot were taken randomly, ground and subjected to chemical analysis by using Gunning and Hibbard’s method of H_2SO_4 digestion and using micro Kjeldahl’s method for distillation (Anon., 1990). Available N % age was determined and multiplied by a constant factor of 6.25 for protein contents in the seed. Leaf area duration (LAD) and crop growth rate (CGR) were estimated following the formula given by Hunt (1978).

The data collected were statistically analyzed by using the computer statistical program MSTAT-C (Freed & Eisensmith, 1986). Fisher's analysis of variance technique and the least significant difference (LSD) test at 5% probability level was employed to compare the treatments' means (Steel *et al*., 1997).

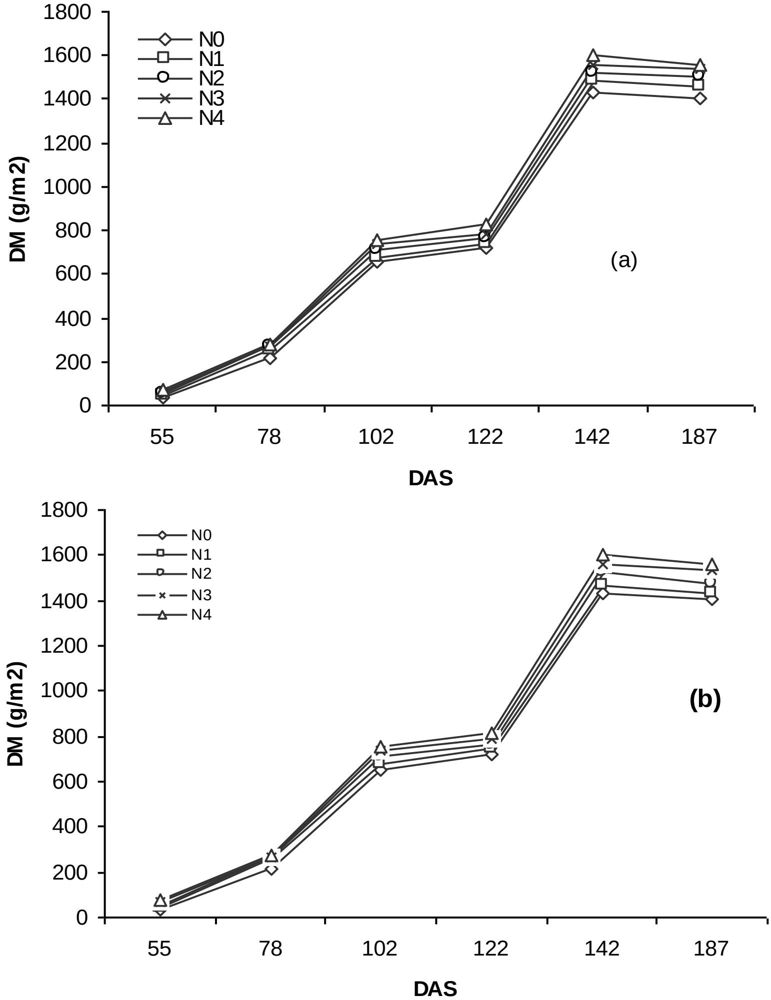
Results and Discussion

Fortnightly recorded data on total dry matter (TDM) accumulation (Fig. 1) showed that it continued to increase up to 142 days after sowing (DAS) and then a steady decline up to final harvest (10^{th} April) was recorded. Similar growth trend in TDM accumulation in Brassica crop were reported by Scott *et al*. (1973) and Allen & Morgan (1975). The differences in TDM accumulation among all the nitrogen treatments were quite obvious from first harvest to final harvest in both the seasons. TDM of final harvest are given in Table 1. In 2001-02 at final harvest, the average TDM yield was 1404 in N_0, 1455 in N_1, 1504 in N_2, 1535 in N_3 and 1560 g in N_4, where N_3 was at par with N_2 and N_4. In 2002-03 the equivalent values varied from 1403 in N_0 (control) to 1563 g in N_4 (120 kg N ha^{-1}) treatment, respectively and all varied significantly from each other. Similar results on growth analyses of canola crop were also reported by Cheema *et al*. (2001) and Zaman (2003) working in similar conditions. At any given harvest, the DM accumulation is a physiological index being closely related to the photosynthetic activity of leaves, which is increased with increasing availability of nitrogen (Kumar *et al*., 1997).

At final harvest, the average TDM yield of present study varied from 14.91 t ha^{-1} in 2001-02 to 14.81 t ha^{-1} in 2002-03, and it increased up to 15.60 t ha^{-1} with increasing rates of nitrogen (N_4) application. The TDM yield is close to those reported in the literature (Allen & Morgan, 1975; Asare & Scarisbrick, 1995; Hocking *et al.*, 1997; Kumar *et al.*, 1997). TDM accumulation however, remained unaffected by timing of nitrogen application.

Crop growth rate (CGR) also followed the same trend as TDM. Data on seasonal average CGR have been shown (Table 1). The leaf area duration (LAD) is an important parameter which accounts for both the magnitude of leaf area and its persistence in time. Each increment of nitrogen fertilizer significantly increased total LAD during both the seasons (Table 1). Similar trend in LAD accumulation was observed during 2002-03 season (Table 1). Scott *et al.* (1973) reported that LAD of oilseed rape was closely related to LAI and TDM, which was greatly increased by nitrogen application, a result similar to that found in this study. Total seasonal LAD was not significantly affected by the time of application during 2001-02 but this effect was significant during 2002-03 (Table 1). The T_3 treatment gave highest LAD (385.2) but it was statistically at par with T_4 and T_2. It showed that split application of nitrogen is advantageous than full application at sowing. The regression analysis indicated significant and linear relationship during both years with coefficients of determination as 0.94 and 0.96 during 2001-02 and 2002-03, respectively (Fig. 2).

Table 1 show that increasing rates of nitrogen significantly enhanced seed yield over lower rates of nitrogen application in both the seasons. In 2001-02 the maximum seed yield (2817 kg ha^{-1}) was recorded by N_4 treatment that was significantly higher over all other treatments (N_0, N_1, N_2 or N_3) while the lowest seed yield (1618 kg ha^{-1}) was exhibited by N_0 (control) treatment. A similar trend was observed in 2002-03 season.



DM = dry matter DAS = days after sowing

Fig. 1. Effect of different N-rates on dry matter of canola during (a) 2001-02 and (b) 2002-03.

The adequate application of nitrogen enabled the crop to make rapid leaf growth to intercept more solar radiation and thus to produce and fill more pods. The effect of time of nitrogen application on seed yield was significant in both the seasons. In 2001-02 the highest seed yield (2427 kgha^{-1}) was produced by T_3 ($^1/_2$ N at sowing + ½ N flowering) treatment, which was statistically at par with T_2 ($^1/_2$ N at sowing + ½ N at branching) treatment. The lowest seed yield (2299 kg ha^{-1}) was produced by T_4 ($^1/_2$ N at branching + ½ N at flowering) treatment followed by T_1 (full nitrogen at sowing) (Table 1). In 2002-03 highest seed yield (2422 kg ha^{-1}) was attained by applying nitrogen in two splits, half at sowing and half at branching or flowering. These results are in line with those of Cheema (1999) and Zaman (2003). This might be due to optimum availability of nutrients at optimum time which played a vital role in the vegetative and reproductive growth of the crop plants.

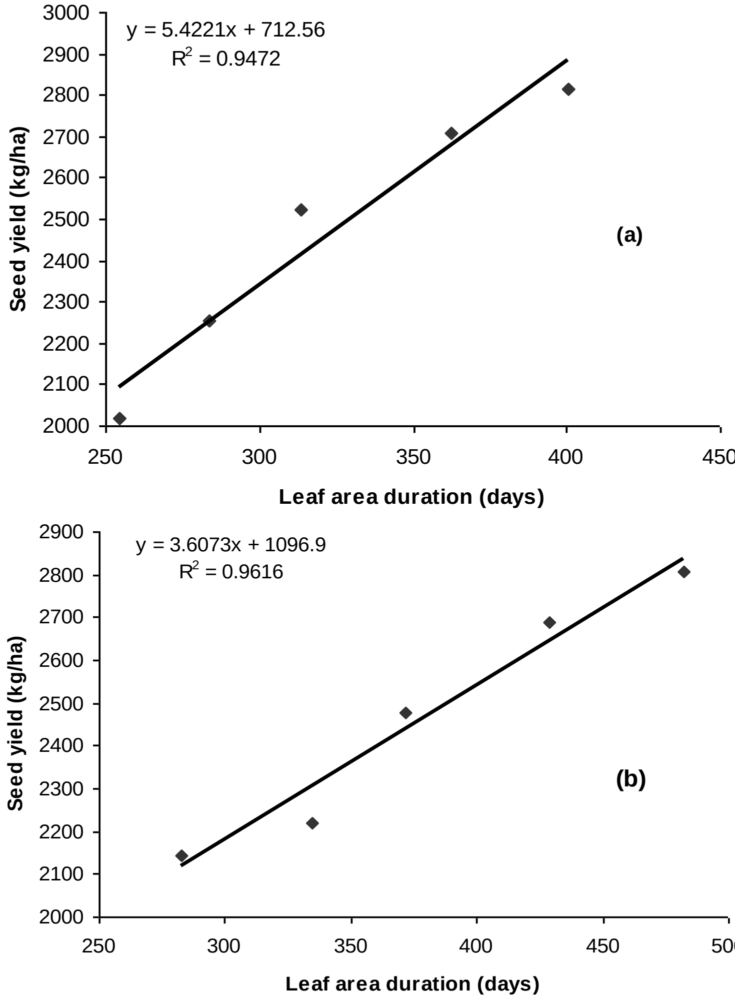


Fig. 2. The relationship between seed yield and leaf area duration of canola during (a)2001-02 and (b) 2002-03.

Nitrogen rates, significantly affected the seed protein contents. Increasing rates of nitrogen application from N_0 to N_4 (0-120 kg ha^{-1}) significantly increased the protein contents during both the years (Table 2). Highest protein percentage (25.96 and 25.97 during 2001-02 and 2002-03, respectively) was found in seeds where nitrogen was applied @ 120 kg ha^{-1}. As nitrogen is an important constituent of protein, therefore, an increased supply of N could be the possible reason of high protein contents in N_4 treatment (Table 2). The promotive effect of different N levels of fertilizer on seed protein contents has also been reported in rape by Marquad & Gendry (1989) and Karaaslan (2008). The time of application had non-significant effect on seed protein percentage during both growing seasons. These results corroborate the findings of Asare & Scarisbrick (1995) who reported a protein content range of 20.8 to 21.4% in oilseed rape.

Table 1. Effect of nitrogen rates and its application timings on growth and seed yield of canola during 2001-02 and 2002-03.

Treatments	Leaf area duration		Total dry matter (g)		Crop growth rate ($gm^{-2}d^{-1}$)		Seed yield (kg ha^{-1})	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
Nitrogen rates (kg ha^{-1})								
0 kg ha^{-1}(N_0)	254.4 e	282.7 e	1404 d	1403 e	10.37 e	10.37 e	1618 e	1745 e
30 kg ha^{-1}(N_1)	283.8 d	334.8 d	1455 c	1430 d	10.49 d	10.51 d	2253 b	2219 d
60 kg ha^{-1}(N_2)	313.7 c	371.5 c	1504 b	1476 c	10.98 c	10.80 c	2523 c	2478 c
90 kg ha^{-1}(N_3)	362.6 b	428.8 b	1535 ab	1533 b	11.13 b	11.10 b	2708 b	2689 b
120 kg ha^{-1}(N_4)	400.4 a	482.4 a	1560 a	1563 a	11.29 a	11.28 a	2817 a	2808 a
LSD (5 %)	18.12	4.70	35.48	7.54	0.02	0.05	17.42	24.40
N application times (T)								
Full N at sowing (T_1)	324.1	365.8 b	1483	1480	10.85	10.80	2398 b	2399 b
½ N at sowing+1/2 N at branching (T_2)	317.9	384.3 a	1488	1480	10.86	10.81	2411 ab	2422 a
½ N at sowing+1/2 N at flowering (T_3)	325.5	385.2 a	1508	1482	10.86	10.83	2427 a	2422 a
½ N at branching+1/2 N at flowering (T_4)	324.4	384.8 a	1487	1482	10.85	10.82	2299 c	2308 c
LSD (5 %)	NS	5.39	NS	NS	NS	NS	28.41	21.67
Interaction (NxT)	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letters within a column do not differ significantly ($P< 0.05$)
NS = Non significant

Table 2. Effect of nitrogen rates and its application timings on protein and oil of canola during 2001-02 and 2002-03.

Treatments	Protein content (%)		Oil content (%)		Oil yield (kg ha^{-1})	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
Nitrogen rates (kg ha^{-1})						
0 kg ha^{-1}(N_0)	21.75 e	21.78 e	46.29 a	46.47 a	748.9 e	808.3 e
30 kg ha^{-1}(N_1)	22.20 d	22.20 d	45.40 a	45.73 b	1029.0 d	1015 d
60 kg ha^{-1}(N_2)	23.78 c	23.77 c	44.75 b	45.04 c	1129.0 c	1116 c
90 kg ha^{-1}(N_3)	24.85 b	24.86 b	43.08 c	44.56 d	1173.0 b	1198 b
120 kg ha^{-1}(N_4)	25.96 a	25.97 a	42.48 c	43.88 e	1197.0 a	1201 a
LSD (5 %)	0.06	0.08	0.86	0.12	8.54	10.34
N application times (T)						
Full N at sowing (T_1)	23.70	23.71	44.57	45.13	1061 a	1078 b
½ N at sowing+1/2 N at branching (T_2)	23.70	23.71	44.63	45.14	1068 a	1090 a
½ N at sowing+1/2 N at flowering (T_3)	23.71	23.72	44.63	45.17	1074 a	1090 a
½ N at branching+1/2 N at flowering (T_4)	23.72	23.74	44.33	45.11	1018 b	1039 c
LSD (5 %)	NS	NS	NS	NS	12.89	13.53
Interaction (NxT)	NS	NS	NS	NS	NS	NS

Means followed by the same letters within a column do not differ significantly ($p< 0.05$)
NS = Non significant

Table 3. Economic analysis of canola as affected by different nitrogen rates.

Treatments Nitrogen rates (kg ha^{-1})	Rs. (kg ha^{-1})			Benefit cost ratio
	Gross income	Total expenditure	Net Income	
2001-02				
0 kg ha^{-1}(N_0)	37945	11606	26339	2.26
30 kg ha^{-1}(N_1)	52350	17052	35298	2.07
60 kg ha^{-1}(N_2)	58425	17548	40877	2.32
90 kg ha^{-1}(N_3)	62628	18135	44493	2.45
120 kg ha^{-1}(N_4)	65182	18232	46950	2.57
2002-03				
0 kg ha^{-1}(N_0)	40847	11606	29241	1.71
30 kg ha^{-1}(N_1)	51599	17052	34547	2.02
60 kg ha^{-1}(N_2)	57394	17548	39846	2.27
90 kg ha^{-1}(N_3)	62200	18135	44065	2.42
120 kg ha^{-1}(N_4)	64943	18232	46711	2.56

Different rates of nitrogen application, significantly affected oil contents in both the years of study. The trend was similar in both years. Maximum oil contents were found in N_0 (control) where no nitrogen was added. N_4 (120 kg N ha^{-1}) treatment gave significantly lower oil contents. However, the time of nitrogen application did not affect the oil contents in both the years of investigation and they varied from 44.33 to 45.17 % among various nitrogen application treatments in both the seasons (Table 2). A significant decrease in oil percentage of the canola and other oil seed crops with increasing nitrogen rates reflects the inverse relationship between oil concentration and seed protein content. Many workers have reported similar results in oil seed crops (Zhao *et al*., 1993; Hocking *et al*., 1997 and Cheema *et al*., 2001). In contrast, Dreccer *et al.* (2000) indicated that the effect of N supply on the oil content of oilseed rape was non significant and Karaaslan (2008) found a significant increase in oil content of canola with increasing levels of nitrogen.

Oil yield depends on seed oil contents and seed yield of oil seed crop per unit area. Different rates and time of nitrogen application significantly affected oil yield in both the years of present study (Table 2). During 2001-02 the highest oil yield (1197 kg ha^{-1}) was produced by N_4 (120 kg ha^{-1}) treatment. The lowest oil yield (748.9 kg ha^{-1}) was observed in control (N_0) treatment. A similar trend of oil yield as affected by various rates of N fertilizer application was also observed in 2002-03 season. The higher oil yield with increasing rate of N fertilizer application was probably due to their higher seed yield. These results are in line with those of Asare & Scarisbrick (1995), Hocking *et al*., (1997) and Cheema (1999). The time of N fertilizer application also had significant effect on oil yield in both the seasons (Table 2). In 2001-02 T_3 ($^1/_2$ N at sowing + $^1/_2$ N at flowering) produced highest oil yield (1074 kg ha^{-1}) which was statistically at par with T_2 & T_1 treatment while the lowest oil yield (1018 kg ha^{-1}) was observed in T_4 ($^1/_2$ N at branching + ½ N at flowering) treatment. During 2002-03 highest oil yield was obtained by applying nitrogen in two splits, half at sowing + half at branching or flowering and it differed significantly from other nitrogen application timings. The decrease in oil yield in T_4 ($^1/_2$ N at branching + ½ N at flowering) was probably due to inadequate supply of N and inefficient utilization of nutrients necessary for early development of roots and growth of canola plant which ultimately increased seed and oil yield.

Details of cost of canola production per hectare under local conditions are given in Table 3. The economic analysis indicated higher net income ha^{-1} in N_4 (120 kg ha^{-1}) treatment over all other rates of nitrogen fertilizer application including the control treatment in both the years. Maximum net return obtained in the N_4 treatment was Rs.46950 in 2001-02 and Rs.47711 in 2002-03. These results are supported by Ahmad (2000) who reported that the highest net income ha^{-1} was at 120 kg N ha^{-1} as compared to 40 and 80 kg N ha^{-1} under similar agro-ecological conditions of Faisalabad. Tahir (2002) reported highest net income at 100 kg N ha^{-1} in canola crop under similar climatic conditions.

Conclusion

Present study indicated that LAD might be used as an indicator of final seed yield. But for general recommendation further studies under different agro-ecological zones using different varieties should be carried out for more years. In addition, it was found that for higher economic yield (seed and oil) of canola cv. Zafar-2000 under irrigated conditions of Faisalabad, nitrogen should be applied @ 120 kg ha^{-1} in two splits (half at sowing + half at branching or flowering).

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