Research Article

Growth and Yield of Turnip (*Brassica rapa* L.) in Response to Different Sowing Methods and Nitrogen Levels in Salt-Affected Soils

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Abstract | Increasing demand for food by expanding population, urged upon the scientists to evolve a site-specific crop production technology which not only increases production per unit area but also ensure the quality of daily dietary crops. For this purpose, a series of field experiments were conducted during 2013 to 2015 with objective to optimizing the different levels of nitrogen and the cost-benefit sowing methods for turnip production under moderately salt-affected soils. The experimental design was split-plot with sowing methods (bed and ridge) in the main plot and nitrogen doses (40, 60, 80 and 100 kg ha^{-1}) as sub plot. Treatments were replicated three times with sub plot size of 4 m × 6 m. Measurements included were: number of plant/m^{-2}, number of leaves/plants, root length, bulb diameter, forage yield and total bulb yield. Results revealed that all the studied parameters were significantly improved with nitrogen application @ 80 and 100 kg ha^{-1} in ridge sowing. However, 80 kg N ha^{-1} in ridge sowing documented maximum economic benefit as compared to other treatments and is suggested as most cost-effective technique for turnip production under moderately salt-affected soils.

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Introduction

Turnip has been cultivated since about 2000 years ago in a vast range of climate from west Europe to China and from Norway to the African desert (Zohary and Hopf, 2000). Turnip can be used for human consumption as well as feed for livestock. 100 gram of turnip bulb contains, 0.12 % Fat, 34 calories, 2.2 % fibers, 7.84 % carbohydrates, no cholesterol and 1.10 % protein (Susan, 2010).

Nitrogen strongly stimulates the plant growth as it is an essential part of protein and it play an important role in photosynthesis. It is an essential macronutrient for plant metabolism reaction and thus affecting yield and quality of a crop (Epstein and Bloom, 2006; Nawaz et al., 2017). Nitrogen management during cultivation in salt-affected soils is of great importance and has to pursue a balanced nitrogen fertilization approach as over-fertilization not only negatively affect the crop yield but also caused the environmental pollution (Songzhong, 2009). All the plants needed nitrogen to thrive as it constitutes almost 80 % of the total mineral nutrients taken up by plants (Marschner, 1995). Under all agro-ecological conditions, an adequate supply of nitrogen is desirable (Fageria and Baligar, 2005) and its balanced use is imperative for the sustainability of cropping-systems.

In Pakistan a large gap is exit between the actual and potential yield of turnip (Baloch, 1994). Turnip shows a positive response to heavy fertilization especially for nitrogen, for satisfactory growth and development (Sharma, 2007; Salardini et al., 2009). Sadia et al. (2013) studied the response of different doses of N on the growth and root yield of turnip and reported that nitrogen at rate of 100 kg ha^{-1} was most optimal level for better growth and root yield of turnip. Nitrogen is most important factor for affecting dry matter yield of leaf and root and crude protein of leaf and in turnip (El-Sherbeny et al., 2012). Evaluating the response of turnip rape seed to different nitrogen rates Ali et al. (1996) stated that nitrogen @ 120 kg ha^{-1} significantly improved the crop yield. In a study conducted by Notman and Mulvany (1994) they suggested that nitrogen fertilization @ 60 kg ha^{-1} and 45 kg P ha^{-1} was optimum level for getting the profitable of yield of turnip cv. Barkant. Begdelo et al. (2011) evaluated the influence of nitrogen increments i.e. 0, 50, 100 and 150 kg ha^{-1} on production of turnip rape under different irrigation regime. They reported that maximum biomass and seed yield, 1000 seed weight and harvest index were achieved by application of 150 kg N ha^{-1} and proved superior over all other treatments. While studying the performance of four turnip cultivars (Agressa, Siloganova, Polybra and Volenda) against four nitrogen's increments (0, 50, 100, 150 and 200 kg ha^{-1}) it was reported that increasing level of N had significant effect on yield and yield components of all the turnip cultivars and maximum yield was obtained where nitrogen was applied @ 150 kg ha^{-1} (Albayrak and Çamaş, 2006).

Turnip tops are relatively more tolerant to salinity than roots Shannon and Grieve (1999 trnp1). Mojarad et al. (2014 trnp1) evaluated the performance of 16 turnip varieties against 4 salinity levels (0.60, 120, 180 and 240 mM). They reported that increasing levels of salinity significantly affected the mean germination and seedling growth.

In Pakistan, 6.67 m ha land is salt-affected (Khan, 1998) which is about 1/3rd of the total cultivated area so there is a great scope to enhance production of vegetables in salt-affected soils by strengthening research and development activities. Keeping in view the advantages of fertilization, many plant scientists had stated that application of N and P alleviate the deleterious effects of salinity on plants (Abu-Romman and Suwwan, 2012; Abu-Romman et al., 2013). Thus, to increase crop production per unit under saline conditions, it is obligatory to manipulate existing cultivation techniques, such as planting time and method, balanced fertilization, proper planting geometry, sowing techniques and other management practices.

Recommended agronomic technologies for salt-affected soils include improved cultivation methods like, seed priming, sowing on raised beds, (Sayre, 2007; Bakker et al., 2010) irrigation at night to control evaporation loss (Rhoades, 1999). Improved sowing methods not only keep appropriate plant population but also help the plants to exploit light, water, land, and other external resources efficiently and uniformly. Due to low porosity and high bulk density, plants root is confined in the upper surface layer of salt-affected soils and consequently soil volume is reduced which could be explored by root for nutrient and water uptake, while in ridges sowing due to fertile and loose layer of upper soil, plant developed a well-established root system (Ao et al., 2010; Khan et al., 2012a). Ridge sowing significantly improved, number of leaves, grain yield, plant height and biological yield of maize as compared to other sowing methods Bakht et al. (2011). Comparing the effect of different sowing, Khan et al. (2000) obtained the highest yield of canola in ridge sowing than other conventional sowing methods as irrigation next to seed flushes the toxic salts away from seed thus creating more favorable growth condition in ridges. Similarly, in a study maximum yield of sunflower was achieved in ridge sowing as compared to other sowing techniques (Malik et al., 2001). So, taking the above facts into consideration, a field study was carried out with objective to interpret an interrelated evaluation of turnip fertilizer requirements and sowing method in salt-affected areas.

Materials and Methods

A field study was conducted from 2013 to 2015 growing season at Soil Salinity Research Institute Pindi Bhattian. Chemical properties of soil used for this experimentation were, the electrical conductivity of soil extract (EC_e) = 4.10 dS m^{-1}, pH of saturated soil paste was 8.67, and sodium adsorption ratio (SAR) = 34.41 (mmol l^{-1})$^{1/2}$. The experimental design was split-plot with sowing methods (bed and ridge) in main plot and nitrogen doses (40, 60, 80 and 100 kg ha^{-1}) as sub-plot. The trial was replicated three times with sub plot size of 6 m x 4 m. Turnip

(*Brassica rapa* L.) cultivar namely 'purple top' was sown @ 8 kg ha^{-1} in last week of August for three consecutive seasons. A fertilizer dose of phosphorus, potassium (50 kg ha^{-1}) and 1/3rd nitrogen as per treatment plan was applied in the form of single super phosphate, sulphate of potash and urea at the time of land preparation. Whereas left over nitrogen was broadcasted at 3rd and 4th irrigations, respectively. All the standard agronomical and management practices were adopted. The data regarding different growth attributes like number of plants/m^2, number of leaves/plants, bulb diameter, root length, forage and bulb yield was recorded and subjected to analysis of variance following the method of Steel et al. (1997). The least significance difference (LSD) test was used to sort out significant differences among treatments means at 5 % probability level using STATISTIX 8.1 package software. An economic analysis was appraised (Shah et al., 2013) to evaluate the economic viability of sowing methods and different nitrogen levels.

Results and Discussion

Number of plants (m^{-2})

A glance on pooled data of three years in Table 1 revealed that number of plants m^{-2}, had linear response with increasing nitrogen levels. Treatment using nitrogen @ 100 kg ha^{-1} yielded the highest number of plants (51.16) followed by 80 kg N ha^{-1} with plant number of (49.16). However, the differences in level of N from 80 to 100 kg ha^{-1} could not produce significant effects on this parameter. The lowest number of plants (42.66) were observed with nitrogen dose of 40 kg ha^{-1}. Sowing method, however, did not show significant effect on number of plants, ridge sowing produced a greater number of plants (49.41) than bed sowing (44.75) nevertheless both sowing methods were statistically ($P \leq 0.05$) similar. Interactive effect of nitrogen levels and sowing method was also significant, data showed that nitrogen @ 100 kg ha^{-1} in ridge sowing documented the maximum number of plants (56.33) which was statistically ($P \leq 0.05$) significant with 80 kg N ha^{-1}with ridge sowing and minimum number of plants (42.33) were recorded in bed sowing at rate of 40 kg N ha^{-1}. In salt-affected soils, among all the essential mineral nutrients, N is one of the most critical growth-limiting macro nutrient (Curtin and Naidu, 1998; Irshad et al., 2002) as due to high pH of these soil it volatilizes into NH_3 (Gupta and Abrol, 1990) and toxic concentration of Cl^{-1} inhibits the uptake of NO_3 (Grattan and Grieve, 1999). According to Gupta and Abrol (1990) under saline environment, an additional 25 % more nitrogen is required by a crop for improved plant growth and development than same cropping pattern used on normal soil. Brassica species are highly responsive to nitrogen and nitrogenous fertilizers are one of main expenses for production as these crops required a large amount of nitrogen (Karakaya and Koch, 1995). In current study, significant increase in number of plants with nitrogen increment can be ascribed as efficient acquisition of absorbed nutrients by roots and enriched nutrition through nitrogen application (Bhakher et al., 1997). The positive effect of nitrogen fertilization on turnip has been documented by several researchers (Keogh et al., 2011; Sadia et al., 2013) which reinforced the findings of present study.

Table 1: *Effect of sowing methods and different rates of nitrogen on number of plants (m^{-2}) of turnip.*

Treatments	Ridge sowing	Bed sowing	Mean
T_1: N @ 40 kg ha^{-1}	43.00 c	42.33 c	42.66 b
T_2: N @ 60 kg ha^{-1}	46.00 c	44.66 c	45.33 b
T_3: N @ 80 kg ha^{-1}	52.33 b	46.00 c	49.16 a
T_4: N @100 kg ha^{-1}	56.33 a	46.00 c	51.16 a
Mean	49.41 a	44.75 a	

Means sharing the same letters are statistically similar at $P \leq 0.05$

Number of leaves/plants

A perusal of data regarding the number of leaves a remarkable positive effect was observed for nitrogen. Results in Table 2 exhibited that number of leaves/plants progressively increased ($P \leq 0.05$) with increasing levels of nitrogen. Pooled data of three years revealed that highest number of leaves (8.43) were recorded in 100 kg N ha^{-1} followed by 80 kg N ha^{-1} and both the treatments were statistically ($P \leq 0.05$) significant from each other and minimum number of leaves (5.41) were noted in nitrogen 40 kg N ha^{-1}. Concerning the sowing methods, ridge sowing gave better results with number of leaves of 7.33 as compared to bed sowing with 6.41 number of leaves. The interactive effect showed that greater number of leaves (9.22) were observed in ridge sowing, where nitrogen was applied @ 100 kg ha^{-1}. Greater number of leaves in ridge sowing may be attributed to fact that ridge sowing provides more satisfactory growth conditions and better nutrient absorption capacity (Bakht et al., 2011). Our results are reinforced by earlier findings of Siddique and Bakht (2005) they reported that maize crop performed better on ridges than other planting methods. The positive role of nitrogen increment on number of leaves may be explained as nitrogen accelerated the synthesis of proteins, chlorophyll, enzymes and consequently carbohydrate synthesis is also enhanced (Bungard et al., 1999). Similar results were reported by Wahocho et al. (2016) that better growth of turnip in term of plant height, number of leaves and root yield can be obtained with nitrogen application @ 110 kg ha^{-1}.

Table 2: *Effect of sowing methods and different rates of nitrogen on number of leave/plant of turnip.*

Treatments	Ridge sowing	Bed sowing	Mean
T_1: N @ 40 kg ha^{-1}	5.70 de	5.12 e	5.41 d
T_2: N @ 60 kg ha^{-1}	6.56 cd	6.16 d	6.36 c
T_3: N @ 80 kg ha^{-1}	7.84 b	6.71 bcd	7.27 b
T_4: N @100 kg ha^{-1}	9.22 a	7.65 bc	8.43 a
Mean	7.33 a	6.41 b	

Means sharing the same letters are statistically similar at P ≤ 0.05

Bulb diameter (cm)

Concerning the bulb diameter, results in (Table 3) showed that nitrogen levels and sowing techniques significantly (P≤0.05) increased the bulb diameter. The average value of three years exhibited that the maximum bulb diameter (7.24 cm) was documented in 100 kg N ha^{-1}, however, it was statistically (P≤0.05) non-significant with 80 kg N ha^{-1} and the lowest value for bulb diameter (4. 40 cm) was recorded in 40 kg N ha^{-1}. Concerning the sowing methods, turnip sown on ridges recorded the highest bulb diameter (6.73 cm) over bed sowing technique (5.68 cm). Nitrogen levels and sowing techniques interaction showed that nitrogen application @ 100 kg ha^{-1} in ridge sowing produced bulb diameter of 7.56 cm nevertheless no significant difference was observed among fertilizer levels of 80 and 100 kg ha^{-1} in ridge and bed sowing. Under salinized environment, one of the most efficient technique to improve crop emergence and stand establishment is to reduce the root zone salinity (Dong et al., 2008). Raised bed render a more surface area as compared to ridge. Consequently, more salts accumulate on beds due to increased upward capillary movement of ground-water driven by evaporation (Qiao et al., 2006; Bakker et al., 2010). Our results are in agreement with the reports of many researchers that in maize, ridge sowing proves superior over any other sowing techniques (Oswald et al., 2002; Rasheed et al., 2003). Previously it was reported by many researchers (Atalay, 1997; Beşpınar, 2003) that root length and root diameter of turnip ranged from 9.07 to 5.13 cm which are in line with our results.

Table 3: *Effect of sowing methods and different rates of nitrogen on bulb diameter (cm) of turnip.*

Treatments	Ridge sowing	Bed sowing	Mean
T_1: N @ 40 kg ha^{-1}	5.25 b	3.55 c	4.40 c
T_2: N @ 60 kg ha^{-1}	6.69 a	5.44 b	6.07 b
T_3: N @ 80 kg ha^{-1}	7.44 a	6.82 a	7.13 a
T_4: N @100 kg ha^{-1}	7.56 a	6.92 a	7.24 a
Mean	6.73 a	5.68 b	

Means sharing the same letters are statistically similar at P ≤ 0.05

Root length (cm)

In respect to root length, pooled data of three years, displayed a distinct effect of sowing methods and successive increasing levels of N on root length as shown in Table 4. Treatment using nitrogen @ 100 kg N ha^{-1} recorded the peak value of root length (12.41 cm) followed by N @ 80 kg ha^{-1} with root length of (11.43 cm) and both treatments were statistically (P≤0.05) significant from each other. Results reflected that ridge sowing documented significantly more root length (11.89 cm) than bed sowing (10.67 cm). Data regarding the interactive effect of sowing technique and nitrogen increments showed that N @ 100 kg ha^{-1} produced maximum root length both in ridge and bed sowing which was statistically alike followed by N @ 80 kg ha^{-1} with ridge and bed sowing respectively. This increased root length with nitrogen increment can be ascribed as efficient acquisition of absorbed nutrients by roots and enriched nutrition through nitrogen application (Bhakher et al., 1997). Furthermore, in ridge sowing, soil is more loosen with better aeration and improved moisture supply and new emerging root suffer minimum resistance and can exploit more surface area for nutrient acquisition, therefore better root growth was observed in ridge sown crop (Chassot and Richner, 2002).

Table 4: *Effect of sowing methods and different rates of nitrogen on root length (cm) of turnip.*

Treatments	Ridge sowing	Bed sowing	Mean
T_1: N @ 40 kg ha^{-1}	11.25 bc	9.22 d	10.23 c
T_2: N @ 60 kg ha^{-1}	11.69 b	10.44 c	11.07 b
T_3: N @ 80 kg ha^{-1}	11.74 b	11.12 bc	11.43 b
T_4: N @100 kg ha^{-1}	12.89 a	11.92 ab	12.41 a
Mean	11.89 a	10.67 b	

Means sharing the same letters are statistically similar at P ≤ 0.05

Forage yield (t ha^{-1})

As seems to be apparent from results, the Table 5 depicted that sowing methods and the additional response of nitrogen fertilization on forage yield was statistically (P≤0.05) significant. Nitrogen @ 100 kg ha^{-1} recorded the highest forage yield (34.97 t ha^{-1}) which was statistically alike with nitrogen @ 80 kg ha^{-1} and consequently minimum forage yield was evidenced in 40 kg ha^{-1} having forage yield of (26.32 t ha^{-1}). In the case of sowing techniques, the highest forage yield (33.97 t ha^{-1}) was observed in ridge sowing which differed significantly from bed sowing with forage yield of 28.99 t ha^{-1}. Interaction between sowing techniques and nitrogen levels depicted that N @ 80 kg ha^{-1} with ridge sowing documented the maximum forage yield (37.27 t ha^{-1}) though no significant difference was observed among N @ 80 and 100 kg ha^{-1} in ridge and bed sowing. Optimal fertilizer dose under salinized environment increased the nutrients contents in soil solution and plant tissue, consequently plant growth is improved (Adediran, 2004) and crop might produce an additional yield of 67 % than normal field (Taiwo et al., 2001). Therefore, optimum N fertilization that exactly fulfill the crop requirement, reduces the risks of nitrogen loss because the plant is well developed and nitrogen is quickly absorbed by this plant (Andraski et al., 2000). Improved forage yield with nitrogen application @ 80 and 100 kg ha^{-1} can be justified to overall increased crop growth and vigor, because of root proliferation to a greater extent, better water and nutrients uptake, more number of leaves, accelerated rate of assimilation and improved photosynthesis (Yadav et al., 2005). Current findings revealed the responsiveness of the turnip to nitrogen fertilization and reinforced the previous outcomes of several researchers that the N contributes markedly to production of forage yield of turnip (Albayrak and Çamaş, 2006; Begdelo et al., 2011; Keogh et al., 2011). Furthermore, evaporation rate is accelerated from extra surface area of bed leading to more salt buildup as compared to ridge (Cardon et al., 2010). Similar findings are stated by Liu and Young (2008) and Belachew and Abera (2010). In an earlier study conducted in Ankara, Karakaya and Altınok (2002) reported a forage yield of (43.47 t ha^{-1}) and root yield of (32.73 t ha^{-1}) from forage turnip. Similarly, Uzun (1990) observed that forage and root yield in turnip were 24.53 t ha^{-1} respectively in Bursa conditions which reinforced the findings of current study.

Table 5: *Effect of sowing methods and different rates of nitrogen on forage yield (t ha^{-1}) of turnip.*

Treatments	Ridge sowing	Bed sowing	Mean
T_1: N @ 40 kg ha^{-1}	27.99 bcd	24.65 d	26.32 c
T_2: N @ 60 kg ha^{-1}	33.50 ab	26.87 cd	30.18 bc
T_3: N @ 80 kg ha^{-1}	37.27 a	31.63 abc	34.45 ab
T_4: N @100 kg ha^{-1}	37.11 a	32.84 abc	34.97 a
Mean	33.97 a	28.99 b	

Means sharing the same letters are statistically similar at P ≤ 0.05

Table 6: *Effect of sowing methods and different rates of nitrogen on yield (t ha^{-1}) of turnip.*

Treatments	Ridge sowing	Bed sowing	Mean
T_1: N @ 40 kg ha^{-1}	31.99 bc	28.65 c	30.32 b
T_2: N @ 60 kg ha^{-1}	37.50 ab	30.87 c	34.18 b
T_3: N @ 80 kg ha^{-1}	41.88 a	36.84 ab	39.36 a
T_4: N @100 kg ha^{-1}	42.65 a	37.95 ab	40.30 a
Mean	38.50 a	33.57 b	

Means sharing the same letters are statistically similar at P ≤ 0.05

Bulb yield (t ha^{-1})

Turnip yield presented in (Table 6) recorded a significant difference among different nitrogen levels and the sowing methods. N @ 100 and 80 kg ha^{-1} were most effective treatments in producing highest yield of turnip i.e. 40.30 and 39.36 t ha^{-1} respectively though both the treatments were statistically (P ≤ 0.05) similar and the lowest yield of turnip (30.32 t ha^{-1}) was recorded where N @ 40 kg ha^{-1} was applied. About the sowing approaches, ridge sowing had more positive effect on turnip yield (38.50 t ha^{-1}) when compared with bed sowing (33.57 t ha^{-1}). Interaction of sowing methods and nitrogen increments showed that maximum turnip yield (42.65 t ha^{-1}) was produced with N @ 100 kg ha^{-1} with ridge sowing and statistically was alike with N @ 80 kg ha^{-1} in ridge and bed sowing while the minimum turnip yield (28.65 t ha^{-1}) was achieved in 40 kg N ha^{-1} with bed sowing. High temperature and inadequate rainfall in Pakistan result very low organic matter in soils consequently nitrogen availability for better plant growth is very low and this situation is exacerbated under saline environment as toxic concentration of Cl^{-1} inhibits the nitrogen uptake (Grattan and Grieve, 1999). Improved turnip yield with N increments may be explained that nitrogen paly a very important role in various plant metabolic processes, photosynthesis, and is also an essential constituent of protein (Epstein and Bloom, 2006) and ultimately final yield is improved. Our results are in strong agreement with earlier

Table 7: *Effect of sowing methods and different nitrogen rates on net income and benefit: cost ratio (BCR) of turnip.*

Nitrogen levels	Sowing methods							
	Ridge Sowing				Bed Sowing			
	Cost of production (Rs.)	Gross income (Rs.)	Net income (Rs.)	Benefit: Cost	Cost of production (Rs.)	Gross income (Rs.)	Net income (Rs.)	Benefit: Cost
N @ 40 kg ha^{-1}	54500	127988	73488	2.34	54500	114600	60100	2.10
N @ 60 kg ha^{-1}	56800	150000	93200	2.64	56800	123480	66680	2.17
N @ 80 kg ha^{-1}	58000	167548	109548	2.88	58000	147360	89360	2.54
N @100 kg ha^{-1}	61900	170612	108712	2.75	61900	151800	89900	2.45

findings that nitrogen has a beneficial effect on turnip yield (Wahocho et al., 2016; Khetran et al., 2016). Current outcomes are also supported by the findings of Choudhary et al. (2008) they stated that under saline environment, salt buildup on top bare surface of the beds, and increased turnip yield in ridge sowing method might be as a result of the more promising soil conditions created by ridges. Ridge sowing resulted in healthier roots system permitting the plants to absorb more nutrients and moisture (Abdullah et al., 2007; Ghaffar et al., 2012).

Economic analysis

Brassica species are highly responsive to nitrogen and nitrogenous fertilizers are one of main expenses for production as these crops required a large amount of nitrogen (Karakaya and Koch, 1995). Economic viability of any innovative technology is very critical for determining its broader adaptability among farming community (Khan et al., 2012b). Economic analysis regarding different sowing methods and nitrogen levels showed that the maximum net income (Rs. 109548 ha^{-1}) with cost benefit ratio of (2.88) was achieved with N @ 80 kg ha^{-1} in ridge sowing when compare with other treatments which may be explained due to more economic yield in this treatment (Table 7). These results are in agreement with findings of Khetran et al. (2016) they described that application of 125-50 and 125-75 NP kg ha^{-1} did not show a significant difference for yield and yield parameters of turnip, therefore they recommended the 125-50 NP kg ha^{-1} as most economical and optimum level for turnip production.

Conclusions and Recommendations

It can be concluded from findings of current study that on the whole, turnip crop performed better with nitrogen application @ 80 kg ha^{-1} in ridge sowing method. The number of plants, number of leaves, forage and turnip yield were significantly higher with N @ 80 kg ha^{-1}. So, these findings suggested that nitrogen application @ 80 kg ha^{-1} in ridge sowing method was optimal fertilizer dose with BCR of 2.54 which may encourage the maximum yield of turnip crop in salt-affected soils.

Author's Contribution

Muhammad Qaisar Nawaz: Conceived the idea, conducted the study for three years, wrote the article.
Khalil Ahmed: analyzed the data, wrote abstract.
Ghulam Qadir: Data collection.
Muhammad Rizwan and Muhammad Faisal Nawaz: Data collection and statistical analysis.
Muhammad Sarfarz: Provided technical input at every step.

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