The Potato Crop in Bihar: Status and Future Challenges

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Introduction

The state of Bihar is located on the fertile lands of the great Indo-Gangetic Plains (IGP). Agriculture is the backbone of the Bihar economy, employing about 80 percent of the workforce and generating nearly 42 percent of the state domestic product (Choudhary, 2011). Bihar's agricultural share of the state GDP is 39 percent, in comparison to 24.3 percent of national share of GDP, due to the fact that 89.5 percent of the state population have a rural and farming background. Bihar ranks 10th in area and 3rd in population with per capita income of about 25 percent of that of the nation. Bihar is the most highly populated state of India with 83 million inhabitants and a population growth of about 2.43 percent per annum. It has the highest population density of rural India with about 40 percent of the population below the poverty line.

According to estimates published by the International Food Policy Research Institute (IFPRI) and the International Potato Centre (CIP), India is likely to have the highest growth rates in potato production and productivity worldwide (Naik and Thakur, 2007). These growth rates indicate a total production in India by 2020 of around 43.3 million mt.

In Bihar, potato is the fourth major food crop after rice, wheat and maize. Although the crop occupies less than five percent of the net sown area across the State, due to its high nutritional value, it is an important source of food for millions of people across Bihar.

Districts of Bihar

Potato has special significance since it gives exceptionally high yields per unit area in a relatively short period. The dry matter production in potato is about 47.6 kg ha^{-1} day^{-1} whereas wheat, rice and maize produce only 18.1, 12.4 and 9.1 kg ha^{-1} day^{-1} respectively (Ezekiel and Pandey, 2008). The task before the state of Bihar is to increase the production and quality of potato to meet domestic requirements and provide surplus for export.

Potato production situation

India is the world's third largest potato producing country. During the past 60 years the potato crop has shown spectacular growth in area, production and productivity in India with increases over this period of 6.6, 18.51 and 2.80 times respectively (Pandey and Naik, 2009). Potato productivity in India (18.4 mt ha^{-1}) is slightly higher than the world average (16.6 mt ha^{-1}) however, it is much lower than many countries in Europe and America, such as The Netherlands (42.4 mt ha^{-1}), mainly because in India it is grown as a short duration crop. The estimated total production in India for 2009-2010 was around 34 million mt from 1.55 million ha. At present, Bihar ranks third after Uttar Pradesh and West Bengal in potato area and production among the different states of India. In Bihar, potato is grown on 0.32 million ha with an annual production of 5.74 million mt and a productivity of 17.78 mt ha^{-1} (Anonymous, 2007). Potato is grown in all 38 districts of Bihar (Table 1 and map), but the major producers are Nalanda, Patna, Vaishali, Saran, Samastipur, Gopalganj, East and West Champaran, Muzaffarpur and Gaya, which account for 80 percent of the area. In terms of productivity, Nalanda, Patna and Vaishali are the foremost districts. Bihar has always been of concern for policy planners because of its low potato productivity despite the fact that it is blessed with highly fertile land and good quality water resources.

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Table 1. Area, production and productivity of potato in major districts of Bihar (2006-2007).

District	Area	Production	Yield
	ha	*mt*	*mt ha*$^{-1}$
Nalanda	27,000	653,320	24.19
Patna	16,050	409,400	25.50
Vaishali	13,500	255,040	18.89
Saran	13,500	249,970	18.51
Samastipur	12,300	250,910	20.39
Gopalganj	12,200	210,470	17.25
W. Champaran	12,200	201,300	16.50
Muzaffarpur	12,000	210,980	17.58
E. Champaran	11,750	202,750	17.25
Gaya	11,500	190,240	16.54
Rohtas	10,700	195,100	18.23
Madhubani	10,600	168,040	15.85
Siwan	10,300	113,460	11.01
Others	149,240	2,430,310	16.28
Total	322,840	5,741,290	17.78

Source: Directorate of Horticulture, Govt. of Bihar.

Crop cultivation scenario in Bihar

Soils

In Bihar, potato is grown under tropical and sub-tropical agro-climatic conditions during short and cool winter days from October-March, where crop duration is between 80-110 days only. Potato is grown in Bihar on a wide range of soils under varied climatic and environmental conditions. There are many types of soil in the state, which differ significantly between different regions as well as within the region itself. A brief description of important soil types in which potato is grown are given below:

1) Young alluvium calcareous soils: These soils occur in the large area of north Bihar associated with the river Gandak in the districts of Muzaffarpur, Samastipur, East Champaran, Southern part of West Champaran, Vaishali, Siwan, Gopalganj and Saran. Soils are light to heavy in texture having more than 10 percent free calcium carbonate ($CaCO_3$), with a maximum limit of up to 60 percent. The pH, EC and organic carbon in these soils vary from 7.7 to 9.8, 0.10 to 4.5 dS m^{-1} and 0.10 to 1.36 percent respectively. Soils are low to medium in available P_2O_5 and K_2O and about 73 percent soils are deficient in zinc.

2) Young alluvium non-calcareous soils: These soils occur in the districts of Madhubani, Darbhanga and Sithamarhi and are associated with the river Bagmati. The soils are neutral to alkaline in reaction and salt concentration can be low to high. Most of the soils are very low to medium in organic carbon, and available P_2O_5 and K_2O content. About 66 percent of the soils are deficient in zinc.

3) Recent alluvium non-calcareous non-saline soils: These soils cover the alluvial plains of Koshi and Mahananda rivers comprising the districts of Saharsha, Madhepura, Purnea and Katihar. Soils are yellowish white, flood-based and are medium to heavy in texture, acidic to neutral (5.6 to 7.3), low to medium in salinity (0.29 to 1.12 dS m^{-1}), and low to medium in available P_2O_5 and K_2O. Around 40-45 percent of these soils are deficient in zinc and boron.

4) Soils of South Bihar, known as old alluvium soils, are affected by the river Ganges. Soils are reddish-yellow to yellow-grey in color with distinct horizon differentiation; soils are slightly acidic to neutral in reaction varying from low to high in salinity, organic carbon, available P_2O_5 and K_2O. Soils of Patna Nalanda, Gaya, Nawada, Jahanabad, Rohtash and Bhojpur are medium to heavy in texture, varying from silty loam to clay loam, while soils of Munger, Sheikhpura, Bhagalpur are light in texture varying from silty loam to loam.

In some areas, two crops of potato can be grown in the same field i.e. early autumn and spring. In the Nalanda district of Bihar, for example, an early crop of potato can be harvested during October-December, and a spring crop during January-March. The produce of the early crop goes directly to the market for consumption whilst the harvest from the main crop is cold stored. In fact, the potato crop can grow and give economic returns under any climate, provided the night temperature during the tuberization phase remains around 20°C.

Crop season

The main potato crop begins with planting in late October to November and is harvested during February to

Spraying potato against disease. Photo by S.K. Singh.

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March. Throughout Bihar, the crop is grown during the main season. In some places, an early autumn crop is also grown, which is planted in September to October and often harvested prematurely in November to December to fetch a better market price. Important regions which grow early crops are Nalanda and the Sone river bed of Bhojpur, Patna and Aurangabad districts. As mentioned above, in some parts of Bihar a spring crop of potato is also grown. Thus, potato in Bihar is grown in different seasons i.e. autumn, winter and spring seasons (Table 2).

Table 2. Typical crop seasons of potato in Bihar.

Crop	Planting period	Harvesting period	Areas[(1)]
Autumn/Early	20/9–31/10	Mid November-December	Nalanda, Patna (15)
Winter/Main	11-mid 12	February-Early March	All Bihar Districts (80)
Spring/Late	Late 12–15/1	Late March	Tarai Region & Nalanda (5)

[(1)]in brackets is the area distribution between the crops (percent).

Agronomic practices

Seed is the most costly input and thus cut pieces of tubers are generally used as seed material in most parts of Bihar. In Patna and Nalanda, where early planting is done, small tubers of 15 to 20 g are preferable to cut pieces. Seed rate is maintained below 20 q ha^{-1}. Row to row space varies from 50 to 60 cm and tuber to tuber 15 to 20 cm. The spacing is closer when a pure crop of potato is taken but when intercrops such as maize, mustard etc. are to be grown, the row spacing should be wider. Planting and other intercultural operations are invariably done manually. Earthing up is done at 25-30 days after planting with top dressing of nitrogen. When intercropping is practiced, a higher ridge is made at planting to avoid the need for earthing up.

Table 3. Potato-based cropping systems prevalent in different districts of Bihar.

Cropping system	Districts
Paddy-potato	Bhojpur, Gaya
Paddy-potato-onion	Patna, Nalanda
Potato-potato-onion	Nalanda
Maize-potato-vegetables	Nalanda, Vaishali, Samastipur
Potato-wheat	Patna (Sone Diara)
Potato-mentha	Muzaffarpur, Begusarai
Rice-potato-jute	Katihar
Maize-potato-green gram	Muzaffarpur, Samastipur
Yam (elephant foot)-potato	Vaishali, Samastipur

Cropping Systems

Potato, being a short duration crop (80-90 days), fits very well as a "sandwich crop" in the most popular rice-wheat cropping system of the state. There is thus great opportunity for vertical increase in area and production of potato without affecting area and production of other crops. Due to prevailing agro-climatic conditions the rice-potato cropping system is at number one position in the State (Table 3). By utilizing residual fertility after potato, raising a third crop has become common practice in the potato growing regions of Bihar giving rise to a number of cropping systems such as rice-potato-onion, maize-potato-green gram, maize-potato-black gram, rice-potato-mentha, rice-potato-bottle-gourd/vegetable, potato-potato-onion and rice-potato-jute. The yam (elephant foot)-potato cycle is a newly emerging profitable cropping system and is being practiced in Vaishali and Samastipur districts (Table 3).

Many intercropping systems are also practiced in Bihar. In north Bihar the most popular system is potato + maize. Other intercropping systems are sugarcane + potato, potato + mustard, potato + radish, potato + pumpkin/bottle gourd and potato + faba bean. East and West Champaran are two districts where potato + sugarcane intercropping is most common. Potato + radish is popular in Nalanda and Patna, whereas, inter-relay cropping of potato +

Potato field in Bihar. Photo by S.K. Singh.

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pumpkin/bottle gourd is popular in Begusarai and Sone river beds.

More recently, potato is being grown in young orchards of mango and lychee and this is proving very remunerative. This practice can be observed in Vaishali and Muzaffarpur districts. In most intercropping except sugarcane + potato, the potato is considered as the main crop and is harvested early, while the intercrop continues to grow till maturity.

In the intercropping systems, the crops are grown in lines/rows. The fertilizer is applied in the rows of the respective crop at the time of planting as well as top dressing. The quantity of fertilizer applied is generally in proportion to the plant population.

Planting of an experimental potato field. Photo by S.K. Singh.

Harvesting

The early crop is generally harvested at 60 to 70 days. The main objective is to earn cash at the earliest opportunity and hence yield is secondary in importance. The yield varies between 120-160 q ha^{-1} depending upon crop maturity.

The main crop is harvested after 75 to 110 days depending upon the varietal maturity, and yield ranges between 175 to 300 q ha^{-1}. Average yield of the main crop is not less than 175 q ha^{-1} if not attacked by late blight. In Nalanda district, cultivation of Kufri Pukhraj has become very popular and the average productivity is 250-300 q ha^{-1}.

Fertilizer management in potato

Potato is a heavy feeder and responds well to the application of both mineral fertilizers and farmyard manure (FYM). Potato has a shallow root system compared to other crops limiting its foraging capacity in the soil. On the other hand, uptake of fertilizer nutrients (NPK) by potato per unit area and time is high due to faster rate during early growth and tuber bulking. The crop benefits from the FYM application, not only from the amount of the nitrogen, phosphorus, potash and other nutrients that it contains but also its improving effect on the tilth and moisture-holding (retaining) capacity of the soils. Application of FYM also meets the secondary and micronutrient needs of the crop. Therefore, well decomposed FYM at 15-20 mt ha^{-1} should be uniformly applied in furrows opened for potato planting.

The crop requires a balanced dose of NPK for optimum production. Nitrogen (N) contributes to the yield by enhancing the number of tubers, bulking rate, bulking period and delay in maturity. Phosphorus (P) is involved in a wide range of plant processes, including development of the root system and enhanced crop maturity. Its application increases the number of medium size tubers per plant. Application of potassium (K) increases plant height, crop vigor and imparts resistance against drought, frost and diseases. Response of potato to N is more pronounced when applied in conjunction with P and K. Combined application of an optimum dose of NPK maximizes the growth and yield of potato and increases efficiency of each nutrient. Application of P, K, and P + K with N increased the yield by 5.6, 6.2 and 26 percent compared to application of N alone. (Singh *et al.,* 2008).

The potato crop responds well to fertilizer depending on inherent soil fertility and the variety grown. The fertilizer needs of potato have been found to vary with the soil and climatic conditions. The optimum dose of inorganic fertilizer depends mainly on the soil type, soil fertility and crop rotation. The optimum rate of NPK fertilization based on tuber yield response under Bihar conditions has been found to be 120-150: 60-80: 80-100 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. The mean response to optimum dose of N, P and K fertilizer was 116, 46 and 51 q ha^{-1} respectively (Singh *et al*., 2008). Therefore, in the absence of soil testing, the crop should be supplied with 60-75 kg N, 60-80 kg P_2O_5 and 80-100 kg K_2O per ha at the time of planting and 60-75 kg N per ha at the time of earthing up one month after planting. Processing varieties of potato like Kufri Chipsona-1, Kufri Chipsona-3 etc. grown specifically to produce large processing grade tubers,

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require 33-50 percent higher rate of fertilization than the recommended dose of potato for direct consumption.

Care needs to be exercised to select a proper source of fertilizer nutrients because of the highly beneficial response of potato to some sources but possible harmful effects of others. At planting, nitrogen can be applied in the form of ammonium sulfate (AS), calcium ammonium nitrate (CAN) or urea. AS is the best source but it is more costly. Urea is the cheapest and most available source of N in India, but is considered less efficient than AS and CAN. Urea is equally efficient when broadcast and ploughed under during land preparation at least 48 hours before planting potato. Topdressing of urea between rows at earthing up is equally efficient to other sources of N. Using CAN, Diammonium phosphate (DAP) or mixed NPK fertilizer combined with urea for basal application at planting and top dressing with urea at the time of earthing up of the remaining dose of N is economical, efficient and safe. Urea alone at planting in excess of 60 kg N ha^{-1} is harmful for emergence of potato. Similarly, ammonium chloride (ACl) is safe at a lower dose of N at 60 kg ha^{-1} at planting. Readily soluble sources of P such as single superphosphate (SSP), triple superphosphate (TSP) and DAP are most suitable for potato.

Sources of K like muriate of potash (MOP) and sulfate of potash (SOP) are equally efficient for potato. Split application of N (half at planting + half at earthing up) is essential for maximizing efficiency. Spraying two percent urea solution 40-50 days after planting corrects visual deficiency symptoms of N, if any. Split application of K is advantageous only in a light textured loamy sandy soil. No benefits from split doses of P are reported, because it is required mostly for early root and shoot growth. Foliar application of P and K was found to be of limited value. Band placement of P fertilizer is invariably better than broadcast, because of fixation of P in most soils. However, methods of placement of K fertilizer in bands at sides or above or below seed tubers or broadcast were equally efficient (Singh *et al*., 2008). Therefore, combined basal application of a full dose of P and K along with half of N at planting is economically efficient and convenient. Moderation in the ratio of fertilization is possible based on soil test values, after calibration, depending upon the soil, climate, season and variety. The fertilizer recommendations should be based on soil and plant tests.

Potassium is an important nutritional factor in crop management, which contributes to production of high yields of quality potato. Potato requires substantial quantity of potassium to produce an optimum yield. However, potassium needs of the crop vary with the agro-climatic region, variety, crop sequence and soil type. A healthy crop of potato removes about 170-230 kg K_2O ha^{-1} from the soil (Trehan *et al.*, 2008). The varietal response to applied K is often related to its yield potential and the number of large sized tubers it can produce. In general, rapid bulking potato varieties producing large size tubers respond more to K than the varieties with small size tubers as application of K is known to increase the tubers size (Trehan and Grewal, 1990).

The ratio of uptake/removal of K from soil is often in excess of the applied K, resulting in negative balance of available K in the soil, particularly in potato-based cropping systems precluding build up of K in the soil. There is a need for revising K fertilizer recommendations in order to overcome the long term depletion of reserves of soil K. Fertilizer doses for potato grown in triple cropping intensity should be raised by 50 percent of the recommended dose in order to increase profit (Sharma *et al.,* 1999). Potato and other heavy feeder crops (rice, onion, maize etc.) in the rotation may induce a severe negative net balance of K in soil over a short time span of four years (Singh and Trehan, 1998). With high crop intensity and high K removal, the soils are likely to become deficient in K with time. Besides, K is highly mobile and the tendency of K leaching to lower soil horizons is high, particularly where the potato crop is irrigated.

Future line of work

The fertilizer recommendation for potato in Bihar is 150-180:60:100 kg ha^{-1} of N, P_2O_5 and K_2O, respectively, although in practice there is much variation within farmers' fields. In general, Bihar farmers are unaware of the benefit of the different fertilizers to be used. Fertilizers are also not available in the market in many of the regions. As such, farmers purchase whatever fertilizer is available in the market and broadcast it on their fields. There is a lack of awareness about correct dose and method of fertilizer application as fertilizers are broadcast rather than being placed in the furrows. Low use of fertilizers and severe imbalance in the N, P & K application ratio and imbalanced fertilization in favor of N and lack of potash application are the major reasons responsible for low production of potato in the State. So far, only blanket fertilizer recommendations have been in vogue and the current fertilizer rates are insufficient to sustain potato production and to replenish nutrient removal by the crop. Besides, most of the farmers in the region are also unable to purchase the required quantity of fertilizer, due to lack of cash as well as non availability of the fertilizer at certain times. In the absence of sufficient soil test support, imbalanced use of fertilizers is often observed. In some areas, higher doses of N and at other places higher doses of P application are common.

In major potato growing areas there is a need for nutrient indexing and development of a nutrient management schedule using diagnostic tools. Parameters relating to nutrient use efficient cultivars need to be established

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and characterized. There is urgent necessity to develop an integrated nutrient management technique for potato by the appropriate combined use of chemical fertilizer, biofertilizers, organics and micronutrients. There is also a need to develop farmer friendly site-specific nutrient management tools in potato production and the selection of suitable varieties to develop appropriate practices for organic potato production.

Opportunities, challenges and strategies for potato crop in Bihar

Land holding in Bihar consists predominately of small farms and holdings with a high degree of fragmentation. About 86 percent of farmers are small and marginal. The average size of holdings is declining, having fallen to around 0.6 ha, and the majority of farmers have less than 1 ha each. The land holding patterns of the state are summarized in Fig. 1.

Under conditions of increasing demand for food and diminishing per capita availability of land for agriculture due to the rising population in India, the importance of potato for ensuring sustainability in agriculture and the food production is immense. Potato is a high yielding crop. Due to a high protein - calorie ratio (17 gm protein: 1,000 kcal) and a short vegetative cycle, potato yields substantially more edible energy, protein and dry matter per unit area and cropping period than many other food crops. It produces 3 kg of protein ha^{-1} day^{-1} as compared to only 2.5 kg ha^{-1} day^{-1} in wheat, 1.2 kg ha^{-1} day^{-1} in maize and 1.0 kg ha^{-1} day^{-1} in rice. This is of considerable importance in India where energy supplies are more readily available than protein supplies.

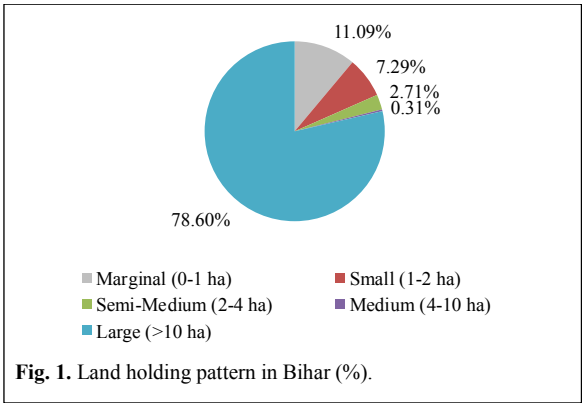

Fig. 1. Land holding pattern in Bihar (%).

Growing potato also provides excellent opportunities to raise farmers' incomes as it has the capacity to yield 5-10 times more than cereals, pulses or oilseeds. The high profitability of potato as a cash crop has made it an economically viable enterprise for small and marginal farmers and has contributed to increasing equity among farmers in the sub-tropics. Potato provides a high unit return and offers great scope for value addition. In this respect the crop generates high employment during production and harvesting. Potato requires an input of 250 man-days for cultivation of the crop per hectare. The cultivation of potato on 1.4 million ha area thus generates rural employment to the level of 350 million man-days annually. The same benefit of employment generation is also true for post-harvest handling including transportation, marketing and processing.

Low productivity is the most vital issue as it directly affects the profitability associated with crop production. Despite favorable soil and climatic conditions, it is a paradox that the productivity of potato crop in Bihar is lower, compared to that of other states and the national average. The factors contributing to low productivity of crops and inferiority of the products are inadequate supply of genuine good quality planting material, low seed replacement rate, poor crop management practices, i.e. lack of irrigation, proper fertilization and plant protection measures, high initial cost etc. Poor investment capabilities of the grower, fragmented small holdings, lack of mechanization and erratic market prices and low returns due to the absence of organized marketing are also important.

Late blight is the predominant disease and is widespread across the State. Adverse climatic conditions, particularly foggy weather in January and occasional rains, favor disease spread. Remedial measures are often difficult, although they can be cost effective but only if the disease is identified correctly in time.

In Bihar, potatoes are harvested in January-March, which is followed by hot summers. Potato cannot be stored under ordinary conditions where high temperature and dry weather prevails soon after its harvest. Therefore, to sustain increased potato production, proper cold storage facilities are essential.

The potato crop is produced seasonally but marketed throughout the year. Due to the lack of cold storage facilities, farmers are unable to keep their produce safely. This compels farmers to sell all their produce immediately after harvest. This causes a sudden price crash during the peak harvesting season and farmers are forced to sell their produce at a very nominal price, well below its value.

Awareness is increasing regarding the suitability of Bihar for producing potatoes fit for processing purposes. Currently potato processing companies are carrying out contract farming and, since there are no potato processing firms in Bihar, they are transporting the stocks to far off places for processing. There is thus an outflow of limited material from the State for processing and it is now highly likely that firms will soon be established within Bihar to make use of the best suited produce for processing.

Potato from Bihar is transported to other markets in the country for which cheap road transport and better marketing facilities are essential. Emphasis should be put on the establishment of new cold stores, processing industries in the

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production catchments to minimize transport cost and create employment opportunities in the rural sector.

Agricultural research institutes/Krishi Vignan Kendra (KVK) can be involved in training and demonstration of packages of practices for organic agriculture and capacity building of the farmers. An appropriate network of extension services needs to be created to stimulate and encourage both top-down and bottom-up flows of information between farmers, extension workers and research scientists.

In India about 73 percent of potatoes are consumed as fresh food in the form of vegetables, 10 percent are used as a seed. Of the remaining 17 percent, less than 4 percent is processed and less than 1 percent exported, with the rest, about 10-12 percent going to waste. In India, potatoes are not currently used for animal feed or as an industrial raw material for production of starch and alcohol.

Conclusions

Potato is one of the few foods capable of nourishing the population of the world. It is estimated that by 2020 India will have a population of 1.3 billion. This will require the country to produce about 49 million tonnes of potato. To achieve this production target, the productivity per unit area and time has to be increased. Adoption of improved technologies is imperative to achieve the desired productivity level. Moreover, there is a challenge to enhance productivity and quality under conditions of shrinking areas of arable land, reduced water availability, changing climatic conditions and expanding biotic and abiotic stresses. However, with an increase in production, recurring gluts are common across the country. The price crashes drastically during months of plenty, leading to distress selling by farmers who therefore incur substantial monetary loss. To absorb excess potato production and sustain growth, there is need for diversified and increased utilization and export of potatoes.

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