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A highly variable rainfall and a growing season which permits crop production much of the year has led to sizable investments in irrigation on the Indian subcontinent. In some areas, irrigation has provided supplemental water during the wet season while in other areas it has permitted the growing of a second or third crop during the dry season.[1] There is a wide variation in the dependability and quality of irrigation in India. It ranges from small private wells which provide relatively assured water supplies to large government built dams which operate with a fair degree of uncertainty as to when and in what quantities water will be available. In 1968-69 the net irrigated area for India was 71 million acres or approximately 21 percent of the net area sown. This represents a 17 percent increase over 1960-61 and a 38 percent increase over 1950-51.

The advent of high yielding varieties (HYV's) and the expanded use of fertilizers has increased returns from irrigation water in selected areas of India. In addition, the growing population and increasing disparity between regions with different resource conditions have helped

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highlight water as an important restraint to increasing agricultural production and to improving regional income distribution.

Even with the importance of additional irrigation in India's effort to increase and stabilize food production, it is not clear how best to expand production through irrigation. Should tube well irrigation be promoted or should the emphasis be on small reservoirs (tanks) or on large dams? Still other important alternatives would be improving water use and management on existing irrigation systems or pricing of water on the basis of quantity used and raising the price to more nearly represent its marginal resource cost.

What irrigation investments offer the highest return is a critical question in the areas with natural conditions suited for irrigation. The possible high returns from improving existing flood irrigation systems through field channels were emphasized by the 1972 Irrigation Commission of India. "The states are unanimous that the absence of field channels has been a major reason for the serious lapse in the utilization of irrigation potentials. In 1966, Mysore state took upon itself the responsibility of excavating field channels. This brought about a spectacular improvement in the utilization of the irrigation potential. Andhra Pradesh took action on similar lines in the Nagarjunsager project and this also had a salutary effect." [8]

This article is concerned with estimating the impacts of installing field channels in terms of differences in production, input use and net returns. The location for the study is the area irrigated by the Hirakud reservoir in Orissa State of Eastern India. In a normal year, the Hirakud reservoir provides irrigation water for 15 percent of the cropland in Sambalpur district or 270,000 acres. Within Sambalpur district a program of providing villages a system of irrigation field channels has been operating since 1966. Such a program should have implications for irrigation investment in the rice areas of Eastern India from Orissa and Madhya Pradesh to Bihar and West Bengal. [6]

The field channel program

On canal irrigated lands, like those found in Sambalpur, water flows continuously by gravity from the canal outlets through numerous fields. The surplus water either accumulates in the low lands or finds some natural drainage stream as an outlet, although many of the natural drains have been blocked by roads.[2] Each outlet provides water for 25 to 125 acres and for as many as 20 farmers. In addition, each farmer may have a number of non-contiguous plots within the area. Farmers have no control over either the timing or quantity of water. If a farmer near the outlet shuts off the water while fertilizing his fields, the farmers below go without water.

In 1966 the Intensive Agricultural District Program (IADP) staff introduced in selected villages a project to demonstrate the value of irrigation field channels. The basic idea was to provide a small unlined channel from the outlet along the field levees to each farmer's plot. This allows each farmer to control the flow of water on his fields. At the same time putting the channel along the levees minimizes the amount of land taken out of production. Initially a major extension effort was required to convince the villagers of the program's utility and to obtain the entire village's approval. Once a village agreed to the project, the IADP staff provided the technical assistance and materials needed to install the field channels and demonstrated the use of high yielding varieties (HYV's), fertilizer and perticides. The villagers contributed the labor required for digging the channels. At the time of this study, field channels had been in use in four villages and were being installed in nine others while a number of other villages were waiting for assistance.

The possible measurable impacts of the field channels include additional land irrigated, changes to more profitable cropping patterns, and greater use of HYV's and other inputs. Both the adoption of relatively more labor intensive crops and a higher intensity of cropping will increase the opportunities for employment in agricultural occupations. In addition, field channel construction and maintenance will increase requirements for labor with low opportunity costs, particularly on farms of 7.5 acres or less.

Village comparison

To measure the economic impacts of the field channel project, four villages from the irrigated area were surveyed during the 1970-71 wet season and again during the 1971 dry season. Two kinds of villages were included: two villages with field channels (improved villages), and two villages which needed to improve their irrigation system (control villages). A random sample of 126 farmers was drawn from the four villages so that approximately 20 percent of the owner-cultivators were included from each group of villages.[3]

There are always subtle differences between villages which cannot be controlled. These differences, such as better leadership, can equip one village for economic improvement but not another. Some of the changes observed in the improved villages may be due to uncontrolled variables which are not duplicated in other villages and, therefore, cannot be attributed to the field channels. However, the adoption rates of HYV's, fertilizer, and pesticides before the program became effective in 1966-67 indicate that the villages were quite similar in their use of new inputs. (See Table 1.) The improved villages

TABLE 1: Percentage of Sample Farmers Using Selected Inputs

Year	HYV's*	Fertilizers	Pesticides
	. . . . (Improved Villages)		
Before 1964	2	12	8
1964-65	3	32	10
1965-66	7	48	18
1966-67	30	68	40
1967-68	57	82	62
1968-69	78	88	73
1969-70	87	92	77
1970-71	95	98	78
	. . . . (Control Villages)		
Before 1964	0	11	0
1964-65	5	23	5
1965-66	9	42	11
1966-67	17	52	17
1967-68	52	82	45
1968-69	75	97	63
1969-70	81	99	63
1970-71	86	100	64

* Before 1966-67 adoption rates refer to locally improved varieties and not what are considered HYV's such as TN-1 and IR-8.

had a slightly higher level of education. But the differences of 0.8 years for the farmer and 0.4 years for the family were not significant at the 5 percent level. Thus the control villages should provide a good basis against which the improved villages can be measured.

The average size of holding in the villages is between six and seven acres and is not significantly different at the 5 percent level. Rice is the major crop with HYV's much more popular in the dry season. (See Table 2.) Wheat, pulses, oilseeds, and vegetables account for only 4 percent or less of the cropped area in any one season. Little area is planted to HYV's during the wet season because of the susceptibility of HYV's to gall midge (insect) attacks and the villagers' preference for consumption of local varieties. The dry season rice crop is the primary cash crop except in the case of small farmers who consume most of both crops.

The important difference among villages is the significantly greater use of HYV's in the improved villages during the dry season. Seventy-two percent of the cropland in the dry season is planted to high yielding rice varieties in the improved villages as compared with only 54 percent in the control villages. Since yield differences between local rice varieties and HYV's are 2.8 to 6.1 quintals per acre, the greater use of HYV's means significantly higher production for the improved villages.

The introduction of field channels did not change the basic cropping pattern in the improved villages. Two rice crops continue to be the basic cropping system. One reason for the lack of change may be that the farmers have not had time to fully adjust to the new cropping alternatives. Another reason is that field channels provide a more assured water supply and have made it unnecessary for farmers to grow crops requiring less water. The

TABLE 2: Crops Grown on Sample Farms by Type of Village, 1970-71

Crop	Wet Season Improved Villages	Wet Season Control Villages	Dry Season Improved Villages	Dry Season Control Villages
	. . (Percentage)+ . . .	. . . . . .	. (Percentage) . .	. .
Local Rice	92	94	27	44
HYV Rice	5	1	72	54
Other*	3	4	1	2

*Other includes oilseed, wheat, pulse and vegetable crops.

+Percentages may not add to 100 due to rounding.

farmers know how to grow rice and hesitate to shift to other crops because of limited knowledge concerning their production and possible returns. Finally, the price of water did not encourage any shift since the per acre water charge was only slightly lower for crops requiring less water than needed for rice.[4]

The differences between the two sets of villages is evident in the rice yields and input use. The improved villages rice yields are 3.5 to 4.8 quintals per acre higher than yields in the control villages with the difference significant at the one percent level (Table 3).[5] Yields increased somewhat with farm size in the control villages during both seasons. The large farmers have yields between 0.7 and 1.7 quintals per acre more than the small farmers. In contrast the medium sized farmers reported the highest yields in the improved villages.[6] Thus, the program does not appear to favor the large farmers on a per acre basis although on a total production basis it does.

Average fertilizer expenditures follow somewhat the same pattern as yields. (See Table 4.) The two main exceptions are: (1) fertilizer expenditure for all farms is significantly different between villages only at the 10 percent level during the wet season; and (2) fertilizer expenditures per acre increase with farm size in both sets of villages. The latter exception supports the idea that the larger farmers in the improved villages may have under-reported yields since they reported the highest fertilizer use.

Farmers in the improved villages spent 12 to 43 rupees per acre more on fertilizer than did the control village farmers. Expenditures on plant protection materials were also significantly higher at the one percent level in the improved villages. During the dry season the improved villages

TABLE 3: Mean Rice Yields on Sample Farms by Farm Size, 1970-71[a/]

Farm Size	Local Varieties				High Yielding Varieties	
	Wet Season		Dry Season		Dry Season	
	Improved Villages	Control Villages	Improved Villages	Control Villages	Improved Villages	Control Villages
	quintals/acre					
Small[b/]	8.3	5.9	13.9	9.0	16.2	12.5
Medium	10.1	6.2	13.3	9.6	19.4	14.1
Large	9.3	6.6	13.7	9.7	18.9	14.2
All Farms	9.2	6.2	13.6	9.5	18.4	13.6

[a/] A quintal equals 100 kgs. or 4.9 bushels in rough rice.

[b/] Control villages have significantly lower yields at the one percent level of significance using the t-test except for small farms during the wet season. The difference for these farms was significant at the two percent level.

TABLE 4: Mean Fertilizer Expenditures by Farm Size, 1970-71

Farm Size	Local Varieties				High Yielding Varieties	
	Wet Season[a]		Dry Season		Dry Season	
	Improved Villages	Control Villages	Improved Villages	Control Villages	Improved Villages	Control Villages
	rupees per acre[c]					
Small[b]	77**	59	101***	87	133*	100
Medium	85***	76	121	83	173*	123
Large	94***	90	141	98	180	128
All Farms	86*	74	122	89	167	124

a/ So little acreage of high yielding rice was grown during the wet season that only local varieties are shown.

b/ The Improved Villages have significantly higher fertilizer expenditures (valued at constant prices) at the one percent level except where indicated as follows:

*10 percent level
**15 percent level
***not significant

c/ One dollar equaled 7.5 rupees at the official exchange rate in 1970-71.

averaged 12 rupees per acre expenditure for plant protection on HYV's as compared with 4 rupees per acre in the control villages. The expenditure is lower for the local varieties: 3 and 7 rupees per acre for the dry and wet season in the improved villages as compared with 1 and 2 rupees per acre in the control villages.[7]

Production Model

The installation of field channels increased production and input use. But how much of the increase can be attributed to the program? Were the increases neutral (upward shift in intercept) or were input productivities changed or were farmers just induced to move from an under-use of inputs to a point closer to an optimum? Further which of the inputs were the most important in explaining differences in production? To help answer these questions a production function model was constructed with yield per acre by type of land as the dependent variable.[8] The independent variables are the per acre expenditures on fertilizer and plant protection materials and man days of planting and weeding labor. Intercept dummy variables were introduced for two land types, two levels of insect damage, high yielding rice varieties, and the improved villages. To test for differences in the productivity of fertilizer, separate coefficients are estimated for the three land types and the two sets of villages. Cobb-Douglas functions were estimated for each crop season.

Since insect damage occurred, to a noticeable degree, only during the wet season, the dummy variables for insect damage were not included in the

$$Y_{ij} = \alpha_0 + \alpha_{11} F_{11} + \alpha_{12} F_{12} + \alpha_{13} F_{13} + \alpha_{21} F_{21} + \alpha_{22} F_{22} + \alpha_{23} F_{23} +$$

$$\beta_1 P_1 + \beta_2 P_2 + \gamma_1 L_1 + \gamma_2 L_2 + \partial_1 D_1 - \partial_2 D_2 - \partial_3 D_3 + \partial_4 D_4 + \partial_5 D_5 + \partial_6 D_6$$

i = Type of villages 1 and 2

j = Type of land 1, 2 and 3

γ = Per acre rice yields in quintals by land type and farm

F = Per acre expenditure on fertilizer and farm yard manure by land type and farm, valued at constant rupee prices

P = Per acre expenditures on plant protection

L = Per acre man days of labor used.

D_1 = Improved villages dummy

D_2 = Medium insect damage dummy (10 to 25 percent crop loss)

D_3 = Heavy insect damage dummy (above 25 percent crop loss)

D_4 = HYV's dummy

D_5 = Berna land dummy (dales)

D_6 = Bahal land dummy (low lands)

dry season function. In addition, insect damage is the only independent variable that would be expected to have a negative effect on rice production. Production should increase as fertilizer and plant protection expenditures and labor use increase. However, during the wet season farmers may have waited too long to apply the insecticides. It was also questionable whether the insecticide was very effective in controlling the gall midge. Thus, a weak relationship was expected between yield and expenditures on plant protection materials.

The three broad land categories, important in the irrigated area, are known locally as Mal (slopes), Berna (dales) and Bahal (low land). Historically the soil fertility varied according to location with Mal being the least productive. Berna lands were next in productivity because water from the Mal lands percolated to these lands along with the soluable nutrients. The Bahal lands were the most productive due to percolation of water and nutrients. But with irrigation and the lack of adequate drainage, this difference has decreased. The heavy fertilizer applications in the dry season and the improvement in the irrigation system may have further reduced the differences in soil productivity. In fact, some of the low lands have become water logged which limits production to rice and reduces yields particularly in the wet season.

The dummy variable for high yielding rice varieties should be positive. As indicated above the HYV's yield considerably more than the local varieties. Only during the wet season might this relationship not hold due to the interaction between varieties and insect damage. Since only twelve farmers planted a total of 25 acres of HYV's in the wet season and half of them experiencing very heavy insect damage, the HYV's part of their acreage is excluded from the analysis.

Finally if the irrigation improvement project increased production through a neutral shift the improved village dummy should be positive and significant. If the increases were due to the greater response to fertilizer the improved village fertilizer coefficients should be significantly higher than those for the control village. On the other hand, the irrigation improvement and demonstration may simply have induced the farmers to use more inputs. In this case the improved village dummy would be insignificant and the fertilizer coefficients would not be significantly different between villages.

In the dry season all the variables had the expected signs except for labor in the improved villages. (See Table 5). For the wet season the Berna land and improved village dummies had negative signs as did labor in the improved villages. However, none of these variables were significant and can be considered as approaching zero. The coefficients of multiple determination are reasonably high for cross sectional farm data, particularly in the dry season. The lower coefficient for the wet season is due to the poor fit of the data from the control village, particularly on Bahal land.

As was expected the fertilizer variables were the most important in explaining rice production for both seasons. In addition high yielding varieties, expenditures on plant production materials and the improved village dummy were significant in explaining the dry season production. In the wet season the medium and heavy insect damage dummies and the Bahal land dummy were significant in explaining production differences.

The dummy variables for HYV's and insect damage provide estimates of net benefits from new rice varieties and insecticides. The HYV's dummy estimates the net annual benefits from existing new varieties while the

TABLE 5: Cobb-Douglas Production Functions for Irrigated Rice Farms in India 1970-71

Independent variable	Dry Season Control Villages	Dry Season Improved Villages	Wet Season Control Villages	Wet Season Improved Villages
Fertilizer on Mal land	.350 (8.6)*	.292 (8.3)	.240 (3.8)	.482 (7.0)
Fertilizer on Berna land	.303 (4.8)	.229 (3.5)	.348 (3.0)	.577 (4.5)
Fertilizer on Bahal land	.316 (6.6)	.244 (6.5)	.090 (1.3)	.336 (3.7)
Plant Protection	.029 (1.3)	.041 (2.5)	.026 (0.6)	.019 (0.5)
Labor	.017 (0.3)	-.042 (0.6)	.067 (0.7)	-.097 (1.0)
HYV's intercept dummy	.088 (5.6)		----	
Berna land intercept dummy	.135 (1.0)		-.172 (0.8)	
Bahal land intercept dummy	.117 (1.3)		.318 (2.1)	
Improved Villages intercept dummy	.305 (2.1)		-.075 (0.3)	
Medium Pest Damage intercept dummy	----		-.051 (1.8)	
Heavy Pest Damage intercept dummy	----		-.120 (3.3)	
Intercept	.254 (2.3)		.254 (1.6)	
R^2	.696		.452	
F	44.08		11.94	

* t - statistic

insect damage dummies estimates potential benefits from gall midge resistant varieties or better insecticides. The net annual per acre benefits for HYV's are 122 kgs. or rupees 61. Discounted at 20 percent over a 10 year period, the net benefits for HYV's are rupees 378 per acre. Since 47 percent of the village acreage had medium insect damage and 16 percent had heavy damage the average annual per acre net benefits of reducing damage is 74 kgs. or rupees 37. Discounted net benefits are rupees 229 per acre. These benefits are valued at rupees 50 per quintal. This is the price received by farmers in the study period and is considerably lower than the current rice prices in India.

Labor was not important in explaining production in either season which one might expect in fairly homogeneous farms where labor use per acre does not vary much. Also the amount of labor used tends to be more a function of availability rather than productivity, particularly on small and medium size farms. Finally farmers had more difficulty recalling the quantity of labor used than any other input and were unable to recall difference in labor use by land type or rice variety.

The difference between fertilizer coefficients from the three land types are consistent for each set of villages. These differences are larger in the wet season which supports the hypothesis that irrigation has reduced the differences between land types. The low coefficients for Bahal land in the wet season is probably the result of poor drainage.

The village dummy was positive and significant for the dry season but not significant in the wet season. This supports the hypothesis that the field channels did raise the level of production during the dry season. In contrast, production was greater in the wet season due to the higher elasticity of production with respect to fertilizer. The difference in fertilizer coefficients between villages is significant at the one percent level using the Chow test as suggested by Abel. [1] The F-statistic of 4.19 for the wet season is over twice that for the dry season. The higher fertilizer coefficients in the improved village during the wet season explain much of the difference in fertilizer use between villages. However, the higher fertilizer coefficients for the control villages during the dry season are in the opposite direction from the wet season. The difference in coefficients may be due to a downward bias in the improved villages. Since the improved villages grew almost 20 percent more HYV's, the HYV's dummy may be picking up some of the fertilizer response. The improved village dummy may also have picked up the effect of fertilizer. Finally, since there is no rain in the dry season water control may not be as important for fertilizer response as it is in the wet season.

The production function shows that the reasons for the increased input use and higher production in the improved villages are quite different in the two seasons. The higher production function as measured by the improved village shift dummy accounts for about 40 percent of the actual yield difference in the dry season. The lower marginal value production in the improved village indicates that the reduced uncertainty concerning water supply and fertilizer loss has allowed the farmers to operate closer to an optimum level of fertilizer use. (See Table 6). In the wet season the higher elasticities of production for fertilizer explain one-third of the actual yield difference between villages. Probably the most important reasons for the higher elasticities are reduced flooding and better field drainage provided by the improved irrigation. The low marginal value products on the Bahal land particularly in the control villages point out the drainage problem which has only partly been corrected by the field channels.

TABLE 6: Marginal Value Products for Rice 1970-71*

	Wet Season		Dry Season	
	Control Villages	Improved Village	Control Villages	Improved Village
	- - - - - - - - -	- - - rupees/rupee- - -	- - - - - - - - -	- - - - - - - - -
Fertilizer on Mal	1.3	2.2	2.3	1.3
Fertilizer on Berna	1.9	2.3	2.0	1.0
Fertilizer on Bahal	0.5	1.3	2.1	1.1
Pesticides	4.5	1.1	7.9	3.6

*Valued at the mean price received by farmers in the villages; rupees 50 per 100 kgs. of rough rice (paddy). The procurement price was rupees 56 per 100 kgs. of rough rice.

Returns

Net benefits are derived directly from the production function. The improved village intercept dummy provides an estimate of dry season benefits while the differences in fertilizer coefficients are a measure of wet season benefits. The dry season benefits are 202 kgs. per acre or rupees 101 and the wet season benefits are 101.3 kgs. per acre or rupees 51. These benefit estimates are lower than the rupees 250-350 obtained in earlier budget analyses. [3,5] However, these lower estimates are probably closer to the benefits which can be attributed directly to the improved irrigation. All benefit estimates are based only on the cultivators rice production and do not include project costs.

The project costs can be divided into technical assistance, cost of structures and the digging of channels. Over half the project costs is the technical assistance which includes the initial contact and village survey, the system design, and the supervision of the installation and maintenance of field channels. The average cost for such technical assistance based on 1971 salaries is rupees 18 per acre. The costs of materials and masonary labor charge is approximately rupees 10 per acre. The labor cost for digging the field channels, the only project cost paid by farmers, is only rupees 6 per acre. With these relatively low project costs, and maintenance costs of only rupees 5 or 6 per acre, the net on farm returns easily covers all project costs. Based on these project costs of rupees 34, a 20 percent discount rate, a 10 year project life and rupees 152 net annual benefits, the benefit-cost ratio exceeds 13. Since 1970-71 was a fairly normal rainfall year the net benefits are probably fairly close to what could be expected over time. But the benefits do not include anything for the additional acreage irrigated in the improved villages or other crops grown.[9] Therefore, the net benefits probably understate the total village benefits.

Conclusions

Without much question one can say that the program of providing field channels has been successful and profitable for the farmers. Production of rice has been increased along with the expenditures on fertilizer and plant protection and the use of HYV's. The farmers have reached a higher production level and have reduced uncertainty in the dry season. For the wet season the improved village had significantly higher response to fertilizer. Translated into returns the farmers could in one normal year pay the program costs and still retain over 75 percent of the increase in net returns. The question still remains why India has not moved more rapidly in improving its existing irrigation? One reason is the lack of technically trained people willing and able to design village irrigation systems. As pointed out above more villages are requesting help in Sambalpur than can be served by existing district staff.[10] Another is the lack of an organized effort to make use of the available technically trained people. Government officials are becoming aware of the possibilities for improving irrigation but are not committed to the needed investments in manpower. Hopefully this work along with others will help push them towards action. [5,9].

Footnotes

1. The wet season is the monsoon or *kharif* season which starts in June and ends in December. The dry season is the winter or *rabi* season which runs from January to May.

2. The heavy textured low lands were the most productive before irrigation water was available. Now the lack of adequate drainage has caused water logging in the low lands while irrigation has increased production on the higher lands. These changes in land productivity have shifted the relative wealth of farmers and caused changes in local leadership. Some individuals from the labor groups bought cheap land which increased greatly in value after being irrigated.

3. The sample was drawn so that a representative sample was also obtained from three size groups: 0.5 to 3.5 acres (small farms), 3.6 to 7.5 acres (medium farms), and above 7.5 acres (large farms).

4. The water charge for an acre of rice was only one rupee more than for an acre of wheat. This was changed in 1971 and the water charges per acre are now more related to water requirements. However, a pricing system based on a fixed charge per acre encourages excessive use of water by farmers who have an adequate supply. Since it is a fixed charge, farmers use water up to the point of zero marginal product from water. Pricing on the basis of volume received would help reduce the overuse of irrigation water.

Water charges on the Hirakud project are among the lowest in India [1, p. 271]. This is the result of the lowering of rates to encourage farmers to use the irrigation waters. During the first years irrigation water was available from the Hirakud dam, farmers refused to irrigate [5]. Currently farmers are demanding as much irrigation water as they can obtain particularly for the dry season. Therefore, water charges should be raised so that they more closely represent the marginal resource cost. Otherwise, you have a rationing problem and a loss in production because of inefficient water use.

5. Not enough high yielding varieties were grown during the wet season to provide a valid comparison.

6. The yields reported, particularly by the large farmers during dry season, may be lower than were actually obtained. Some of the large farmers were a little reluctant to give complete information during the second interview. They were concerned that the State Government might obtain the information and charge them a state income tax. This could explain the lack of relationship between farm size and yield particularly for the <u>improved</u> villages.

7. The farmers reported that the field channels eliminated the fear of fertilizer being washed away by irrigation water. The actual amount of fertilizer washed away may be small, but the belief that it was being washed away influenced the amount of fertilizer farmers applied.

8. The analysis was done on a per acre basis because of the very high intercorrelation between land and fertilizer when land was included as an independent variable.

9. The improved villages increased the cropland irrigated from 84 percent before field channels to 97 percent in 1970-71. Cropping intensity increased from 187 percent to 196 percent during the same period. The control villages had 84 percent of the cropped area irrigated and a cropping intensity of 185 percent.

10. In addition some farmers are trying to put in field channels without technical assistance. The results from these efforts have not been very encouraging. First farmers have difficulty in obtaining a proper lay out and second other farmers served from the same outlet may not cooperate.

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