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Validation of Maize-Common Bean Intercropping on Crop Productivity and Land Use Efficiency Under Two Tillage Practices at Jimma Zone, South Western Ethiopia

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Abstract: Validation of maize common bean intercropping on crop productivity and land use efficiency under two tillage practices was conducted to determine the best maize common intercropping ratio and tillage practice. Four treatments with farmers replications which were two maize to common bean ratio:- 1:2 and 1:4 maize to common bean ratio respectively in rows of maize and between two maize plant stand and two tillage practices:- conventional tillage and zero tillage. The design used was split plot design. The collected date was subjected to ANOVA using SAS version 9.3. Significant highest grain yield of maize 4060 kg ha^{-1} and above-ground biomass 10.08 ton ha^{-1} was recorded from zero tillage with the highest net benefit 24,898.0 ETB ha^{-1}. Whereas the significant maximum grain yield of common bean 1270 kg ha^{-1} and above- ground biomass 3.87 ton ha^{-1} was obtained from one maize to four common bean intercropping ratio with highest net benefit 15,345ETB ha^{-1} Therefore, it is advisable for farmers in the study area and adjacent district' with similar agro-ecologies, one maize to four common bean intercropping ratio with zero tillage practice can be the best combination for yield improvement of the both crop and land use efficiency.

Keywords: Grain Yield, Intercropping, Tillage Practice

1. Introduction

Intercropping is a type of mixed cropping and defined as the simultaneous cultivation of more than one crop species on the same piece of land Hauggaard-Nielsen et al. [1] which aims to match efficiently crop demands to the available growth resources and labor. The most common advantage of intercropping is the production of greater yield on a given piece of land, improves soil fertility through biological nitrogen fixation with the use of legumes, increases soil conservation through greater ground cover than sole cropping, and provides better lodging resistance for crops susceptible to lodging than when grown in monoculture. Intercrops often reduce pest incidence and improve forage quality by increasing crude protein yield of forage. Intercropping also provides insurance against crop failure or against unstable market prices for a given commodity, especially in areas subject to extreme weather conditions such as frost, drought, and flood. Moreover, intercropping allows lower inputs through reduced fertilizer and pesticide requirements, thus minimizing environmental impacts of agriculture Lithourgidis et al. [2].

For the success of intercropping system several aspects need to be taken into consideration before and during the cultivation process Seran and Brintha [3]. Those considerations include maturity of crop, compatible crops, time of planting and plant density. The choice of compatible crops depends on the plant growth habit, land, light, water and fertilizer utilization Brintha and Seran [4]. When two or more crops are grown together the peak period of growth of components do not coincide so as to make their major demands on resources at different times. Plant competition could be minimized not only by spatial arrangement, but also by choosing compatible crops which are able to exploit soil nutrients Seran and Brintha [3].

The primary rationale for this combination of practices is to protects the natural resource base for agriculture (preventing soil erosion) thereby contributing to maintenance of long-run agricultural productivity. Conservation Agriculture is proposed to be widely applicable to areas and regions where it is not currently practiced. It is also believed to effectively be applicable irrespective of size of land area and agro-ecologies [5]. Therefore it is, containing combination of tested scientific technologies, and its practice in Africa is now taking roots with increasing demand for more sustainable agricultural practices and better natural resources management and conservation Thiombiano and Meshack [6] and it is increasingly promoted in Africa as an alternative for coping with the need to increase food production on the basis of more sustainable farming practices.

However, a research has not been conducted with regard to identification of ratio of common bean to maize intercropping and land management particularly in the study area so that growers could not get enough information on the productivity of the intercropped component crops. Thus, further research on identifying ratio of intercropping was done for three years at Jimma area and further evaluation and validation was done during 2019 main cropping season with objective to validate maize-common bean inter cropping and land use under two tillage practices.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Kersa and Omonada district of Jimma zone South Western Ethiopia during main cropping season of 2019. Kersa woreda was located on latitude 7º42'N and longitude 36º59'E and laid at an altitude of 1753 m.a.s.l. The average minimum and maximum temperature is 6ºC and 25.5ºC, respectively with 1712 mm per annum precipitation during cropping season. Whereas, Omonada woreda was located on latitude 7º37'N and longitude 37º14'E and laid at analtitude of 1753 m.a.s.l. The average minimum and maximum temperature is 6ºC and 25ºC, respectively and reliably receives good rains 1446 mm per annum cropping season. The soil type of the experimental area was Eutric-nitisols (reddish brown).

2.2. Soil Physico-chemical Properties

The average soil pH of the trial sites ranges from 5.08 to 5.22 across locations, which was strongly acidic [7] and ideal for the production of most field crops. The pH of the soil affects maize growth by suppressing the root development and reducing availability of macronutrients to plants especially phosphorus Brady and Weil [8]. The soil total N of both location mean was 0.17 and SOM ranges from 3.22 to 3.29% were found medium rate for crop growth and development for both nutrients [9]. For all locations the Bray II extractable available P ranges from 9.00 to 23.42 mg kg^{-1} which was above the critical level (8 mg kg^{-1}) for most crops as described by Tekalign and Haque [10].

Table 1. *Selected Physico-chemical properties of the soil of the experimental sites before planting.*

Soil characters	Location	
	Kersa	**Omonada**
pH(1:2.5)	5.22	5.08
Available P(mg kg^{-1})	23.42	9.00
Total N (%)	0.17	0.17
OC (%)	1.91	1.87
SOM (%)	3.29	3.22
C:N ratio	11.05	12.45

Where pH= Hydrogen power, OC=Organic carbon, TN=Total Nitrogen, Av P=Available Phosphorous, SOM=Soil Organic Matter. Values are the means of duplicated samples.
Source: Jimma Agricultural Research Center soil and plant laboratory

2.3. Description of the Experimental Materials

Hybrid maize variety BH661 and Nasir variety of common bean was used in the present study. The maize variety BH661 is the most promising variety released by Bako Agricultural Research Centre and adapted well to the agro-ecologies of Jimma and Buno Bedele areas.

2.4. Experimental Treatments and Procedures

The experimental field that received conventional tillage was ploughed and prepared well before planting at all locations and the field that received zero tillage was applied by round-up chemical before one month to control the weed and prepare for planting both crops. The maize was planted during 18 up to 22 May at different locations and the common bean intercropped based on the treatment at maize planting. Three maize seeds were planted per hill and then thinned to two plants per hill after good establishment of seedlings so as to maintain a single healthy plant per hill. This experiment had four treatments with farmers replications which were two maize to common bean ratio:- 1:2 and 1:4 maize to common bean ratio, respectively in rows of maize and between two maize plant stand and two tillage practices:- conventional tillage and zero tillage. The treatments were laid out in split plot design with farmers replications. The plot size 48m^2 (4.8 m x 10 m) was used for each treatment.

Nitrogen and phosphorus fertilizers were applied, respectively per stand or hill base. Nitrogen fertilizer rates were applied during planting and knee height stage to increase the nitrogen use efficiency. All other agronomic practices were applied uniformly to all experimental plots in the study area.

2.5. Data Collected

2.5.1. Plant Height (cm)

It was measured at ground level to terminal stem using measuring stick at the point where the tassel starts branching from six randomly selected plants for maize and it was measured by centimeters from the ground level to the top of the plant at 50% flowering from 5 randomly selected plants from each plot for common bean.

2.5.2. Number of Ear per Plant

It was obtained by counting total number of ears in each plot and divided to total number of plant stand harvested.

2.5.3. Stem Diameter (Girth)

It was measured at 50cm from the ground level on six randomly selected plants using caliper.

2.5.4. Grain Yield (kg ha^{-1})

Grain yield per plot was recorded using electronic balance and then adjusted to 12.5% moisture for maize. For common it was measured from each plot and then adjusted to 7.0% moisture and converted to hectare basis.

2.5.5. Above-ground Biomass (kg ha^{-1})

For maize all aboveground biomass was harvested from net plot and weighted, ears were removed and weighted separately, six plants were selected, chopped and oven dried till get uniform weight. Whereas for common bean all above ground biomass was harvested from net plot and weighted, sample plants were selected dried till get uniform weight.

2.5.6. Lodging Percent

It was obtained by counting the total number of stalk and root lodging in each plot and divided to the total number of plant stand at harvesting.

2.5.7. Harvest Index

Was calculated as the ratio of grain yield to above-ground biomass yield on dry weight basis [11] for both maize and common bean.

$$\mathrm{HI}(\%) = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Total biological yield (kg ha}^{-1})} \times 100$$

2.5.8. Number of Pods Per Plant

The number of pods was counted from five randomly selected plants of harvestable rows at the time of harvesting from each plot and their averages were recorded for common bean.

2.6. Data Analysis

Analysis of variance (ANOVA) for all collected data was computed using SAS version 9.3 statistical software. Whenever the ANOVA results showed the significant differences between sources of variation, the means were compared using least significant difference (0.05%). The homogeneity test was done as suggested by Gomez and Gomez [12].

2.7. Partial Budget Analysis

Partial budget analysis was performed to investigate the economic feasibility of the treatments and assess the costs and benefits associated with different treatments of common bean intercropped and tillage practices. The partial budget technique as described by CIMMYT [13] was applied. The partial budget analysis was done using the prevailing market prices for seed inputs of common bean and cost for tillage practice performed at planting and for outputs at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopian Birr (ETB). The inputs and/or concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross field benefit (GFB) ha^{-1} (the product of field price and the mean yield for each treatment), cost of labor spent on chemical application, preparation of the land, the total costs that varied (TVC) which included the sum of field costs.

3. Results and Discussions

The homogeneity test of the error variances over locations indicated that the error variance was homogenous and hence combined analysis of variance was conducted. Over locations combined analysis (Table 2) indicates the interaction and main effect of maize common bean ratio didn't show significant (P >0.05) difference on plant height, number of ear per plant, stem diameter (girth), lodging percent, grain yield and HI of maize. However, the tillage practice was significantly (P ≤0.05) affected plant height, number of ear per plant, lodging percent, grain yield and aboveground above-ground biomass of maize but no significant effect (P >0.05) on stem girth and harvest index of maize. On other hand, tillage practice and maize common bean ratio had highly significant (P ≤0.01) interaction effect on grain yield of maize.

Table 2. *Mean square values of tillage practices and maize common bean ratio on growth, yield and yield components of maize.*

Parameter	Mean square for source of variation				
	Tillage practice (1)	Maize common bean ratio (1)	Interaction (1)	Error a (4)	Error b (8)
Plant height(cm)	661.25**	31.25^{ns}	266.45^{ns}	79.57	266.5
Ears per plant	0.018*	0.007^{ns}	0.0039^{ns}	0.0036	0.0039
Girth(cm)	0.00196^{ns}	0.1164^{ns}	0.0014^{ns}	0.0285	0.0014
Lodging (%)	202.95*	3.436^{ns}	8.3076^{ns}	46.978	8.31
Grain yield (kg ha^{-1})	2423472.2**	175219.2^{ns}	684500^{ns}	298170.6	684500
AGBY (t ha^{-1})	6.938**	1.897^{ns}	4.494**	0.496	4.49
Harvest index	0.0039^{ns}	0.0005^{ns}	0.000001^{ns}	0.0015	0.000087

*Numbers in parenthesis = Degrees of freedom; *= Significant (P ≤ 0.05); ** = highly significant (p≤0.01) difference; NS= non significant; AGB= Above ground biomass; ha = Hectare

Concerning the effect of tillage practices and maize common bean ratio on growth, yield components and yield of common bean, maize common bean was highly significantly (P ≤0.01) affected grain yield and aboveground biomass of common bean. In other case, tillage practice and interaction effect of the two didn't show significant (P>0.05) difference on plant height, number of pod per plant, grain yield and above ground biomass of common bean. However, tillage practice highly significantly (P ≤0.01) influenced harvest index of the common bean. Whereas, harvest index was not significantly (P>0.05) affected by their interaction effect (Table 3).

Table 3. *Mean square values of tillage practices and maize common bean ratio on growth, yield and yield components of common bean.*

Parameter	**Mean square for source of variation**				
	Tillage practice (1)	**Maize common bean ratio (1)**	**Interaction (1)**	**Error a (4)**	**Error b (8)**
Plant height(cm)	164.74^{ns}	38.64^{ns}	414.05^{ns}	271.2	414.05
Pod per plant	11.25^{ns}	103.058^{ns}	22.05^{ns}	25.77	22.1
Grain yield (kg ha^{-1})	17224.3^{ns}	360227.69^{**}	4768.798^{ns}	40952.3	4768.8
AGBY (t ha^{-1})	0.535^{ns}	3.724^{**}	0.011^{ns}	0.3196	0.011
Harvest index	0.0013^{**}	0.0002^{ns}	0.00008^{ns}	0.00016	0.00008

*Numbers in parenthesis = Degrees of freedom; *= Significant ($P \leq 0.05$); ** = highly significant ($p \leq 0.01$) difference; NS= non significant; AGB= Above ground biomass; ha = Hectare

3.1. Plant Height

Over location mean indicated the significant highest plant height of maize 266.7cm was recorded from zero tillage while the conventional tillage gave the lowest plant height 255.2cm (Table 4). Highest plant height of maize under zero tillage might be due to the presence of higher crowding effect of the plant and other resources that decrease in the stem diameter and number of green leaves. This could be attributed to the ample soil cover for the zero tillage plots which conserves soil moisture as well as the decomposition of the slashed residues that improve on the fertility of the soil and thus enhancing crop growth. These results are similar to those by Sornpoon and Jayasuriya [14] who reported taller corn plants in the minimum tillage plots.

3.2. Number of Ears Per Plant

Over location mean indicated that the maximum number of ears per plant (1.02) of maize was obtained from zero tillage practice, while the minimum number of ears per plant (0.96) was recorded from conventional tillage practice (Table 4). The reduced tillage practice increased 6.3% number of ears per plant of maize over conventional tillage practices. This might be due to efficiently use of the crop to the nutrient and water, which in turn had increased the nutrient availability for vigorous plant growth Rockstrom et al. [15] thus might have increased the number of ears $plant^{-1}$.

3.3. Grain Yield

The response of grain yield of maize to tillage practices indicates the significant highest grain yield 4060 kg ha^{-1} was recorded from zero tillage. While, the lowest grain yield of maize 3370 kg ha^{-1} was recorded from conventional tillage (Table 4). The data also showed that practicing zero tillage there was 20.5% grain yield increase over the conventional tillage. Regarding grain yield of common bean the significant highest grain yield 1270 kg ha^{-1} was recorded from one maize plant to 4 common bean ratio, while, the lowest grain yield of common bean 1000 kg ha^{-1} was recorded from 1 maize plant to 2 common bean ratio (Table 5). It showed that by planting one maize plant to 4 common bean ratio there was 27.0% grain yield increase over the 1 maize plant to 2 common bean ratio. The yield increase with no-tillage was likely due to better weed control and water conservation compared with conventional tillage Nezomba et al. [16]. Water conservation was probably improved with no-tillage, especially as significant soil water was probably lost with ploughed tillage and the extra weeding. Farmers weeded only once with no-tillage, as compared to twice with conventional tillage, and achieved better weed control. The yield reduction due to intercropping can be attributed to competition for moisture, nutrients and solar radiation associated with intercropping mixtures Belel et al. [17]. According to Matusso et al. [18] crops with C4 photosynthetic pathways have been known to be dominant when intercropped with C3 species. The shading of the bean by the taller maize plants may also have contributed to the reduction of the yields of the intercropped bean Belel et al. [17].

Table 4. *Over location main effect of maize common bean intercropping ratio and tillage practices on growth, yield and yield components of maize at Omonada and Kersa districtJimma zone in 2019 main cropping season.*

Tillage practices	**Over location**						
	Plant height (cm)	**Girth (cm)**	**Lodging (%)**	**EPP**	**Grain yield (kg ha^{-1})**	**AGB (kg ha^{1})**	**HI**
Conventional Tillage	255.2b	2.33	33.6	0.96b	3370b	8900b	0.40
Zero Tillage	266.7a	2.31	27.3	1.02a	4060a	10080a	0.43
LSD (0.05)	8.69	0.16	6.68	0.059	530	690	0.04
CV (%)	3.42	7.26	22.5	14.7	7.42	9.5	6.1
F-test	**	NS	NS	*	**	**	NS
Maize common bean ratio							
1 maize:2 common bean	262.2	2.40	30.87	0.97	3810	9800	0.41
1 maize: 4 common bean	259.7	2.25	30.05	1.01	3620	9180	0.42
LSD (0.05)	8.69	0.16	6.68	0.059	530	690	0.04
CV (%)	6.26	1.60	9.46	6.3	18.3	17.3	2.3
F-test	NS	NS	NS	NS	NS	NS	NS

LSD= Least significant difference; CV=Coefficient of variation; NS=Non significant; HI= Harvest index; AGB= aboveground ab biomass; Values followed by the same letter within a column are not significantly different at P< 0.05.

3.4. Above-ground Biomass Yield

As regards to the effect of tillage practices on above-ground biomass of maize, the obtained results clearly indicated that the significant highest 10080 kg ha^{-1} was recorded from zero tillage while, the lowest above-ground biomass 8.90 ton ha^{-1} was recorded from conventional tillage (Table 4). The zero tillage increased 13.3% above-ground biomass of maize over conventional tillage practice. Regarding the common bean the highest above-ground biomass 3.87 ton ha^{-1} was recorded from one maize plant to four common bean ratio, while the lowest 3.01 ton ha^{-1} was obtained from one maize plant to two common bean ratio (Table 5). There was an increase of 28.6% above-ground biomass of common bean by planting one maize to four common bean ratio over one maize plant to two common bean ratio. This indicated that an increase in common bean plant intercropped increased above-ground biomass yield because the plant per meter square area increase and consequently the above-ground biomass. The low competitive capacity of legumes compared to the cereals has been ascribed to its short root system, shallow root distribution, resulting to low competitive ability for mineral nitrogen Mucheru –Muna et al. [19].

Table 5. *Over location main effect of maize common bean intercropping ratio and tillage practices on growth, yield and yield components of common bean at Omonada and Kersa woreda Jimma zone 2019 main cropping season.*

Tillage practices	Over location				
	Plant height (cm)	**No. of pod plant^{-1}**	**Grain yield (kg ha^{-1})**	**AGB (kg ha^{-1})**	**HI**
Conventional Tillage	93.9	24.9	1160	3610	0.32b
Zero Tillage	88.16	23.4	1110	3280	0.34a
LSD (0.05)	16.05	4.95	200	550	0.012
CV (%)	18.1	18.0	17.8	16.4	3.8
F-test	NS	NS	NS	NS	**
Maize common bean ratio					
1 maize:2 common bean	89.6	26.4	1000b	3010b	0.33
1 maize: 4 common bean	92.4	21.9	1270a	3870a	0.33
LSD (0.05)	16.05	4.95	200	550	0.012
CV (%)	19.4	16.4	6.1	3.1	2.7
F-test	NS	NS	**	**	NS

LSD= Least significant difference; CV=Coefficient of variation; NS=Non significant; HI= Harvest index; AGB= Above-ground biomass; Values followed by the same letter within a column are not significantly different at P< 0.05

3.5. Harvest Index

Harvest index is the ratio of grain yield to total above-ground biomass and the obtained result was in the acceptable range of 0.4 - 0.6 for maize [20]. Regarding the common bean the significant highest harvest index 0.34 was obtained from zero tillage, while conventional tillage gave the lowest harvest index 0.32 (Table 5). This increased the harvest index by 6.3% over conventional tillage practice.

3.6. Partial Budget Analysis

The economic analysis was performed using partial budget analysis following the procedure described by CIMMYT [13] in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Ethiopian Birr (ETB). The total costs of NP fertilizer (13.5 ETB kg^{-1}) and urea = 10 ETB kg^{-1} were calculated based on store sale prices of both district farmers' cooperative in May, 2019 and sale of grain maize and common bean at both district open market average price 7 and 15 ETB kg^{-1} respectively in December, 2019. The cost common bean seed purchase was also used for analysis. Grain yield was adjusted by 10% for management difference to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment Getachew and Taye [21, 13].

The partial budget analysis of maize grain yield presented in Table 6 indicates that the highest net benefit 24,898 ETB ha^{-1} and 23,103 ETB ha^{-1} was obtained from zero tillage practice and one maize to two common bean ratio respectively. It shows there were 28.9% (5587 ETB ha^{-1}) and 10.0% (2097 ETB ha^{-1}) increase over conventional tillage and one maize to four common bean ratio respectively.

Table 6. *Partial budget analyses of tillage practices and maize common bean intercropping ratio on grain yield of maize at Omonada and Kersa district during 2019 cropping season.*

Tillage practices	GY (kg ha^{-1})	Adj.GY (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})
Conventional Tillage	3370	3033.0	21231	1920.0	19311.0
Zero Tillage	4060	3654.0	25578	680.0	24898.0
Maize common bean ratio					
1 maize:2 common bean	3810	3429.0	24003	900.0	23103.0
1 maize: 4 common bean	3620	3258.0	22806	1800.0	21006.0

*GY= Grain yield; GFB = Gross field benefit; TCV = Total cost that varied; NB = Net benefit;
ETB = Ethiopian Birr; Price of chemical fertilizer = 13.5birr kg^{-1}; Price of Urea = 10 birr kg^{-1}; Wage rate = 40 Birr man-day^{-1}; Retail price of grain = 7 birr kg^{-1}.

Table 7. *Partial budget analyses of tillage practices and maize common bean intercropping ratio on grain yield of Common bean at Jimma zone during 2019 cropping season.*

Tillage practices	GY (kg ha^{-1})	Adj.GY (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})
Conventional Tillage	1160	1044.0	15660	1920.0	13740.0
Zero Tillage	1110	999.0	14985	680.0	14305.0
Maize common bean ratio					
1 maize:2 common bean	1000	900.0	13500	900.0	12600.0
1 maize: 4 common bean	1270	1143.0	17145	1800.0	15345.0

*GY= Grain yield; GFB = Gross field benefit; TCV = Total cost that varied; NB = Net benefit;
ETB = Ethiopian Birr; Price of chemical fertilizer = 13.5birr kg^{-1}; Price of Urea = 10 birr kg^{-1}; Wage rate = 40 Birr man-day^{-1}; Retail price of grain = 15 birr kg^{-1}.

Regarding partial budget analysis of common bean grain yield as indicated in Table 7, the highest net benefit (14305 ETB ha^{-1}) and 15345 was obtained from zero tillage practice and one maize to four common bean ratio respectively. The same table also shows that planting one maize to four common bean ratio with zero tillage practice increased the net benefit by 21.8% (2745 ETB ha^{-1}) and 4% (565 ETB ha^{-1}) as compared with one maize to two common bean ratio and conventional tillage practice respectively.

4. Conclusions and Recommendation

Intercropping maize with common bean leads to the production of greater yield on a given piece of land. It also improves soil fertility through biological nitrogen fixation, increases soil conservation through greater ground cover than sole cropping, within a practice of appropriate tillage practice. The experiment was conducted to validate maize common bean inter cropping and land use under two tillage practices at Jimma zone, South Western Ethiopia.

The result srevealed that the tillage practices significantly increased maize grain yield and above-ground biomass yield whereas maize common bean did not significant effect on the maize yield. In other case the maize common bean intercropping ratio significantly affected the grain and above ground biomass yield of common bean, whereas tillage practices did not.

The significant maximum grain yield (4060 kg ha^{-1}) and aboveground biomass (10.08 ton ha^{-1}) of maize was recorded from zero tillage with the highest net benefit 24,898.0 ETB ha^{-1}. Whereas the significant maximum grain yield of common bean 1270 kg ha^{-1} and aboveground biomass 3.87 ton ha^{-1} was obtained from one maize to four common bean intercropping ratio with highest net benefit 15,345ETB ha^{-1}. Therefore, in conclusion one maize to four common bean intercropping ratio with zero tillage practice can be the best combination for yield improvement of the both crop and land use efficiency in the study area and similar agro-ecologies. Please include land equivalent ratio.

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