Annals of Plant and Soil Research 25(4): 595-602 (2023)
https://doi.org/10.47815/apsr.2023.10309

Crop residue retention and herbicide application on performance of maize (*Zea mays* l.) Under conservation agriculture in vertisol of central India

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Received: May, 2023; Revised accepted: September, 2023

ABSTRACT

A field experiment was conducted at ICAR-Indian Institute of Soil Science (IISS), Bhopal Madhya Pradesh, India to study the effect of crop residue retention and herbicidal weed control treatments on crop growth and yield characteristics of maize in Vertisols of central India. The experiment consisted of four levels of crop residue (CR) retention ($CR_{0\%}$, $CR_{30\%}$, $CR_{60\%}$ and $CR_{90\%}$) of previous chickpea and four herbicidal weed control treatments (H_1- Tembotrione @ 120 g a.i. ha^{-1}+Atrazine @ 1 kg a.i. ha^{-1} as pre-emergence (PE), H_2 - Tembotrione @ 120 g a.i. ha^{-1} +Atrazine @ 625 g a.i. ha^{-1} as post-emergence (PoE), H_3 - Tembotrione @ 180 g a.i. ha^{-1} +Atrazine @ 1kg a.i. ha^{-1} (PoE), H_4- H_2 followed by one hand weeding at 50 days after sowing (DAS). Data on crop growth, yield parameters and nutrient uptake by maize were recorded. The performance of maize was recorded to be significantly higher under $CR_{90\%}$ as compared to $CR_{0\%}$. Among herbicidal weed control treatments, plant height and dry matter at harvest, grains row^{-1}, grains cob^{-1}, test weight, grain and stover yield, and nutrient uptake in H_4 were significantly superior over rest of the herbicidal weed control treatments. The interaction effect of crop residue retention and herbicidal treatments could not attain the level of significance. Thus, it can be concluded that the retention of $CR_{90\%}$ and H_4 proved to be best treatment from crop performance and nutrient uptake point of view under conservation agriculture among various treatments evaluated.

Keywords: Conservation agriculture, Crop residue retention, Herbicide application, Maize yield, Nutrient uptake

INTRODUCTION

Intensive tillage practices result in deterioration of soil health through soil structure degradation, surface crusting and compaction (Bhan and Behera, 2014). Conservation agriculture (CA) has emerged as one of the most potential technologies to address the problems of natural resource degradation and environmental pollution, while enhancing and sustaining the system productivity. Maintaining soil health is also important as it is directly responsible for long-term sustainable crop production (Meena *et al*. 2019). Conservation agriculture is a subset of agricultural intensification with sustainability. The concept of CA encompasses conservation, improvement and judicious utilization of natural resources *i.e*., soil and water resources besides external inputs. The concept of CA revolves around three basic principles *i.e*., reduction in tillage, retention of crop residues and crop diversification (Vishwakarma *et al*. 2023). It is well documented that zero tillage and crop residue management improve soil health (Yadav *et al*. 2019) and quality by enhancing soil characteristics, minimising soil erosion, lowering soil water evaporation and preserving soil moisture. As a result, reduced tillage practices have been increasingly popular in recent decades as an appealing alternative to conventional tillage due to their potential to lower operating/production costs and save significant time in seedbed preparation when compared to traditional tillage practices (Al-Kaisi and Yin, 2004). Application of crop residues either on the surface or incorporation into the field has been proved to be beneficial in many of the different cropping systems like rice-wheat (Yaduraju *et al*. 2002), soybean-wheat (Lenka *et al*. 2022) and maize-chickpea (Singh *et al*. 2011). Maize is the third major cereal in the world after rice and wheat having 5% of global acreage and contributing 2% of world production. In India, maize occupied about 9.86 million ha (243.76 lakh acres) area during 2020-21 with a production of

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31.65 million tonnes (MAFW, 2022). The area under maize in Madhya Pradesh is 1.46 million ha with a production of 3.58 million tonne (MAFW, 2022). Hence, evaluation of maize performance under CA shall also open up many new avenues of obtaining better production goals to fulfil the future demand for human food. However, the major obstacle in large scale adoption of CA based production systems is weed management which is considered to be major daunting task because of weed seed burial and lack of tillage operations that destroys vegetative structures (Chauhan *et al*. 2012). Weed competition has been shown to affect maize output by up to 50-68% when weed control is delayed (Rana *et al.* 2012). Weeding in maize after the key period of weed removal might result in grain production losses of up to 83% (Ehsas *et al*. 2016). This shows the relevance of weed management in conservation tillage systems in achieving equivalent/higher yields over conventional tillage systems (Nalewaja *et al*. 2001). Thus, proper weed management needs special attention for the successful adoption of CA on a large scale. Information regarding the impact of zero tillage with residue management as well as herbicide management on crop performance and nutrient uptake by maize as related to seasons, particularly in the fine-textured Vertisols of central India region has not been studied in detail. Therefore, the present investigation was undertaken to study the effect of crop residue retention and herbicide weed control practices on crop performance and nutrient uptake by maize in Vertisol of Central India to maximize crop yield and improve nutrient uptake.

MATERIALS AND METHODS

Field experiments were conducted during the *kharif* season of 2020-21 and 2021-22 at ICAR-Indian Institute of Soil Science (IISS), Bhopal, India under an ongoing CRP-CA (Consortium Research Platform on Conservation Agriculture) experiment, to study the effect of crop residue retention and herbicidal weed control treatments on crop growth and yield characteristics of maize crop in Vertisols of central India. The experimental site is located between 23°18'28.26''N and 77°24'26.00''E at an altitude of 485 m above sea level. The 10-year average rainfall in the experimental area is 1146 mm, of which more than 80% occurred from June to September. The experimental area had a mean annual air temperature of 25 °C. The climate of the region is generally humid subtropical, with hot and dry summers and warm and humid monsoons beginning in late June and ending in late September. The soil of the experimental site is deep clay (Typic Haplustert) in texture (24.5% sand, 23.5% silt and 47.4 % clay) having swelling and shrinkage characteristics upon wetting and drying. The experimental plots consisted of four levels of crop residue retention $CR_{0\%}$- No/nil crop residue retention, $CR_{30\%}$- 30% crop residue retention, $CR_{60\%}$- 60% crop residue retention and $CR_{90\%}$- 90% crop residue retention) of previous crop (chickpea)) and four herbicidal weed control treatments (H_1- Tembotrione @ 120 g a.i. ha^{-1}+Atrazine @ 1 kg a.i. ha^{-1} (Pre-emergence, PE)), H_2 - Tembotrione @ 120 g a.i. ha^{-1} +Atrazine @ 625 g a.i. ha^{-1} (30 days after sowing (DAS)), H_3 - Tembotrione @ 180 g a.i. ha^{-1} +Atrazine @ 1kg a.i. ha^{-1} 30 DAS, H_4- received same herbicide treatment as H_2 followed by hand weeding at 50 DAS). A uniform application of paraquat @1 kg a.i. ha^{-1} was applied for the control of existing weeds in the field. The experiment was laid out in a randomized block design (factorial) with 16 treatments and replicated thrice. Maize crop variety “Nath Samrat 1144 (Hybrid)” was sown with the recommended seed rate 25 kg ha^{-1}, at spacing of 55 cm × 20 cm with the help of happy-seeder and fertilizer dose of 120:60:40 N: P_2O_5:K_2O kg ha^{-1} was uniformly applied in all the plots. The pre and post emergence herbicidal weed control treatments were applied as per treatments with the help of a knapsack sprayer using 500 litres of water ha^{-1}. The data on crop growth parameters were recorded at 30 DAS and at harvest. Three plants were selected randomly from each plot for the measurements of growth and yield attributes (the samples were air-dried for 2-3 days and then oven dried at 65 °C until a constant weight was achieved). After harvesting, threshing, cleaning, and drying, the grain yield was recorded. The stover yield was obtained by subtracting the grain yield from the total biomass yield, and the harvest index (HI) was calculated as the ratio of grain yield and biological yield (grain+stover). The standard method of “Analysis of variance” was used for analysing the data (Gomez and Gomez 1984). Standard error of the means (S.Em ±) was worked out for each factor and interactions. The least significant difference test was used to interpret the treatment effect at the 5% level of significance ($p < 0.05$).

RESULTS AND DISCUSSIONS

Growth parameters

The data regarding plant height and dry weight plant^{-1} is presented in Table 1. A perusal of data revealed that the plant height and dry weight at 30 DAS recorded no significant difference under different levels of crop residue retention. In general, the plant height and dry weight varied between 39.9 to 40.7 cm and 18.26 to 19.56 g plant^{-1}, respectively under different treatments. At harvest, the plant height and dry weight were found to be significantly influenced due to crop residue retention treatments. The maximum plant height and dry weight (166 cm and 248 g plant^{-1}, respectively) were observed under $CR_{90\%}$ which was statistically at par with $CR_{60\%}$ (164 cm and 243 g plant^{-1}) and significantly superior to $CR_{30\%}$ (163 cm and 239 g plant^{-1}) and $CR_{0\%}$ (155 cm and 229 g plant^{-1}) plots. It was observed that retention of crop residue had positive impact on growth of maize as compared to no crop residue retention. Better moisture retention, lesser weed infestation/competition and better micro climate under residue mulch might be the reason for increased plant height and higher dry matter of plants. Significant effect of mulching has been recorded on plant height and dry matter over no-mulching. The present findings were in accordance with the earlier findings where mulching has been reported to result in increased plant height over no-mulching (Singh *et al*. 2015; Khedwal *et al*. 2018). Among herbicidal weed control treatments, plant height and dry weight were not significantly different at 30 DAS among the treatments, but were found to be significantly influenced at harvest (Table. 1). The plant height and dry weight (166 cm and 250 g plant^{-1}, respectively) were recorded in the post emergence (PoE) application of herbicidal weed control treatment (H_4) which was significantly higher as compared to rest of pre- and post-emergence application of weed control treatments. However, the PoE application of herbicidal weed control treatments *i.e*., H_2 (162 cm and 239 g plant^{-1}) and H_3 (163 cm and 242 g plant^{-1}) were at par to each other. All the PoE application of herbicide treatments were observed to be significantly superior to the PE application of herbicide treatment (H_1) (158 cm and 228 g plant^{-1}). It might be due to higher weed density and suppression of the vegetative growth of the plant by weed competition in H_1 than other treatments where post-emergence herbicides were applied. Herbicide application limited weed growth which in turn provided less competition to crops for space and nutrition, allowing the crops to develop more successfully. Similar results were also reported by Malviya and Singh (2007).

Table 1: Effect of crop residue retention and herbicidal weed control treatments on plant height and dry weight plant^{-1} of maize in vertisol

Treatments	Plant height (cm)		Dry weight plant^{-1} (g)	
	pooled		pooled	
Crop Residue (CR)	30DAS	At harvest	30DAS	At harvest
$CR_{90\%}$	40.7	166	19.5	248
$CR_{60\%}$	40.7	164	18.6	243
$CR_{30\%}$	40.0	163	18.2	239
$CR_{0\%}$	39.9	155	18.7	229
S.Em. ±	0.27	0.71	0.73	1.61
CD (P=0.05)	NS	2.06	NS	4.66
Weed Management (H)				
H_1	40.3	158	19.0	228
H_2	40.4	162	18.8	239
H_3	40.3	163	18.5	242
H_4	40.4	166	18.6	250
S.Em. ±	0.27	0.71	0.73	1.61
CD (P=0.05)	NS	2.06	NS	4.66
Interaction (CR X H)				
SEm.±	0.53	1.43	1.46	3.23
CD (P=0.05)	NS	NS	NS	NS

CR: Crop residue, DAS: Days after sowing, H: Herbicidal treatment

Yield attributes

Effect of crop residue retention and herbicidal weed management on yield attributes *viz*., number of grains row^{-1}, grains cob^{-1}, and the test weight were observed to significantly differ among the treatments however, the interaction effect was not significant (Table 2). Among different levels of crop residue retention, higher number of grains row^{-1}, grains cob^{-1}, and the test weight (28.0, 348 and 250 g, respectively) were registered under $CR_{90\%}$ level that was statistically at par with $CR_{60\%}$ level (27, 341 and 249 g) and significantly superior over the $CR_{30\%}$ (25.7, 333 and 248 g) and $CR_{0\%}$ (23.5, 300 and 244 g) crop residue retention. The $CR_{60\%}$ was at par with $CR_{30\%}$ with respect to number of grains cob^{-1} and test weight while it was observed to be significantly superior with respect to number of grains row^{-1}. It was observed that the all the yield attributes *i.e*., number of grains row^{-1}, grains cob^{-1}, and test weight were significantly higher under crop residue retention treatments as compared to no crop residue retention treatment ($CR_{0\%}$).

Table 2: Effect of crop residue retention and herbicidal weed control treatments on number of grains row^{-1}, grains cob^{-1} and test weight of maize in Vertisols

Treatments	Grains Row^{-1}	Grains Cob^{-1}	Test weight (g)
Crop Residue (CR)	pooled	pooled	pooled
$CR_{90\%}$	28.0	348	250
$CR_{60\%}$	27.0	341	249
$CR_{30\%}$	25.7	333	248
$CR_{0\%}$	23.5	300	244
S.Em. ±	0.39	3.52	0.56
CD (P=0.05)	1.11	10.1	1.63
Weed Management (H)			
H_1	23.9	306	243
H_2	25.7	329	247
H_3	26.2	336	248
H_4	28.4	352	252
S.Em. ±	0.39	3.52	0.56
CD (P=0.05)	1.11	10.16	1.63
Interaction (CR X H)			
S.Em. ±	0.77	7.04	1.13
CD (P=0.05)	NS	NS	NS

This could be related to the possible benefits of residue retention as mulch on reduced water loss, reduced runoff, weed suppression, enhanced soil organic carbon, and improved soil structure (Kumawat *et al*. 2020). The present findings were in accordance with the earlier findings of Shah *et al*. (2014) and Pradhan *et al*. (2018) who reported that among different methods of establishment, the yield-attributing characters, such as, grain rows cob^{-1}, grains cob^{-1} and 1000 grain weight in maize were higher with zero tillage (ZT)-bed + residue followed by ZT + residue and conservation tillage (CT)-without residue. In the case of herbicidal weed control treatments, the number of grains row^{-1}, grains cob^{-1}, and the test weight were significantly influenced as result of PE and PoE applications of herbicide treatments. Maximum number of grains row^{-1}, grains cob^{-1}, and the test weight (28.4, 352 and 252 g respectively) were registered in the PoE application of herbicide treatment H_4 which was significantly higher as compared to rest of herbicidal weed control treatments. However, the PoE application of herbicidal weed control treatments in H_2 (25.7, 329 and 247 g) and H_3 (26.2, 336 and 248 g) were at par with each other. Post emergence application of herbicide treatments was significantly superior to the PE application of herbicide treatment. This might be due to better partitioning of photosynthates from source to sink as a result of decreased competition and increased crop growth parameters (Zhu *et al*. 2010; Tesfay *et al*. 2014).

Yield parameters

The grain and stover yield (Fig. 1) were significantly influenced as a result of crop residue retention and herbicidal weed control

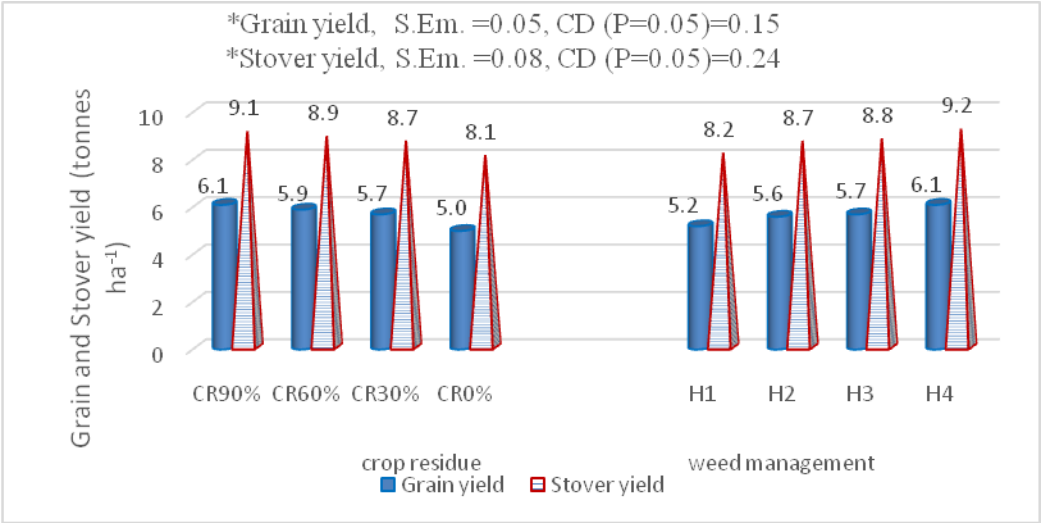

Figure 1: Effect of crop residue and herbicidal weed control treatments on grain and stover yield of maize in Vertisols

treatments. The interaction effect of crop residue and herbicidal weed control treatments on yield parameters was non-significant. The highest grain yield (6.1 tonnes ha^{-1}) was obtained under $CR_{90\%}$ which was significantly higher than the rest of crop residue retention levels and $CR_{0\%}$ had the lowest grain yield. However, the $CR_{60\%}$ (5.9 tonnes ha^{-1}) recorded significantly superior grain yield than the $CR_{30\%}$ (5.7 tonnes ha^{-1}). The maximum stover yield and harvest index (HI) (9.1 tonnes ha^{-1} and 39.86%, respectively) were obtained in the crop residue retention treatment $CR_{90\%}$ which was at par with $CR_{60\%}$ (8.9 q ha^{-1} and 39.5%) and significantly superior to $CR_{30\%}$ (8.7 tonnes ha^{-1} and 39.2%) and $CR_{0\%}$ (8.1 tonnes ha^{-1} and 38.24%). Residue retention improved the stover yield and HI as compared to no crop residue retention. This might be due to more moisture retention and lesser weed infestation under residue retention Apart from acting as a mulch, long-term residue retention effectively increases the soil organic matter, which in turn helps in improved nutrient mineralization and mobilization (Kumawat *et al*. 2020). Previous studies have proven that mulching effectively increased the kernel yield and stover yield of maize (Hijam *et al.* 2014; Sing *et al.* 2015). Residue retention improved grain yield, stover yield and HI as compared to without residue under both ZT and raised bed methods of planting (Khedwal *et al*. 2018). Similarly, Rajkumara *et al*. (2014) reported that application of crop residues @ 5 tonnes/ha under no tilled conditions significantly increased the maize grain yield over no crop residues. Among herbicidal weed control treatments, maximum grain and stover yield, and HI (6.1 tonnes ha^{-1}, 9.2 tonnes ha^{-1} and 39.8%, respectively) were observed in the PoE application herbicidal weed control treatment (H_4) which was significantly higher as compared to the rest of the herbicidal weed control treatments. The PoE application herbicidal weed control treatments *i.e*., H_2 (and H_3 exhibited similar effect on grain, stover yield and HI whereas PE application of herbicide had the lowest grain and stover yield, and HI (5.2 tonnes ha^{-1}, 8.2 tonnes ha^{-1} and 38.5%). This might be due to increased growth parameters such as, plant height and dry matter in lower weed density treatment. All these growth parameters resulted in enhanced dry matter production because of maintenance of weed-free environment throughout crop period (Gavande *et al*. 2022; Sharma *et al*. 2018).

Total Nutrient Uptake

The nutrients such as, nitrogen (N), phosphorus (P) and potassium (K) uptake were significantly influenced due to crop residue retention and herbicidal weed control treatments (Table 4). The interaction effect of crop residue and herbicidal weed control treatments on nutrient uptake was non-significant. Among crop residue retention levels, maximum total N, P, and K uptake by maize (139 N, 33.0 P and 135 K kg ha^{-1}, respectively) was recorded under $CR_{90\%}$. With respect to K uptake, $CR_{90\%}$ and $CR_{60\%}$ were at par with each other. However, $CR_{90\%}$ was significantly higher with respect to N and P uptake (134 N and 31.7 P kg ha^{-1}). However, residue retention helped in superior nutrient uptake in crops compared to no residue

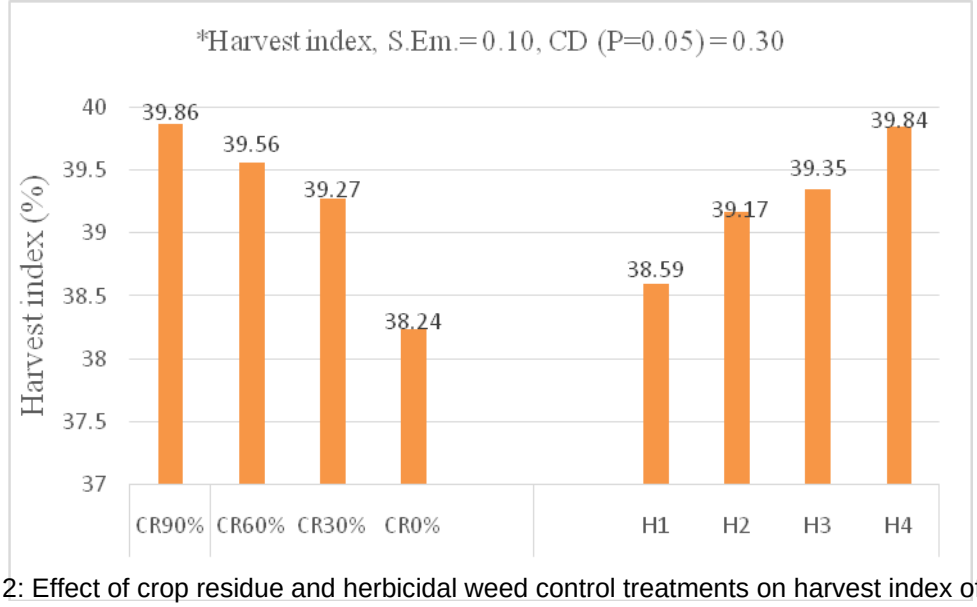

Figure 2: Effect of crop residue and herbicidal weed control treatments on harvest index of maize

retention (Sinha *et al*. 2018) and residues covering seeds are known to prevent their germination by obstructing light penetration, decreasing soil temperature, affecting soil moisture, and reducing oxygen availability. Higher levels of residue retention are known to lower weed emergence, weed dry weight and less nutrient depletion by weeds thus facilitating more plant dry matter production and increased nutrient uptake by maize grain and stover (Nikolic *et al*. 2021). In the case of herbicidal weed control treatments, the nutrient uptake (N, P and K) was significantly influenced as a result of PE and PoE application. Maximum total nutrient uptake (140 N, 33.1 P and 137 K kg ha^{-1}, respectively) was noted in the PoE application of herbicide treatment H_4 followed by H_3 and H_2 which were statistically at par. This could possibly be attributed to higher weed control efficiency resulting in more favourable environment for growth and development of crop plants apparently due to the lesser weed competition (Kour *et al*. 2014). The lowest nutrient uptake was observed in PE application of herbicides (H_1). This is due to fact that weed suppress the vegetative growth of plants by competition for light, moisture and nutrient (Chalka and Nepalia 2006).

Table 3: Effect of crop residue retention and herbicidal weed control treatments on total nutrient (NPK) uptake by maize in Vertisol

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Crop Residue (CR)	pooled	pooled	pooled
$CR_{90\%}$	139	33.0	135
$CR_{60\%}$	134	31.7	132.
$CR_{30\%}$	128	30.1	128
$CR_{0\%}$	115	27.2	117
S.Em. ±	1.49	0.38	1.52
CD (P=0.05)	4.30	1.09	4.39
Weed Management(H)			
H_1	117	27.4	117
H_2	129	30.4	128
H_3	131	31.0	130
H_4	140	33.1	137
S.Em. ±	1.49	0.38	1.52
CD (P=0.05)	4.30	1.09	4.39
Interaction (CR X H)			
S.Em. ±	2.98	0.75	3.04
CD (P=0.05)	NS	NS	NS

Based on above results, it can be inferred that residue retention and herbicide application significantly affected the crop growth, yield parameters and nutrient uptake in maize crop. The highest values of crop performance was observed at the 90% crop residue retention ($CR_{90\%}$) and the treatment H_4. Hence, it can be concluded that under conservation agriculture practices, retention of 90% crop residue along with application of Tembotrione @ 120 g a.i. ha^{-1} +Atrazine @ 625 g a.i. ha^{-1} (30 DAS) followed by hand weeding at 50 DAS can help in improving crop growth, yield characteristics, and nutrient uptake by maize crop.

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