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Tillage Practices Affect Rhizospheric Moisture Availability and Performance of Chickpea (*Cicer arietinum* L.) Cultivars under Spate Irrigation in Punjab, Pakistan

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A B S T R A C T

Selection of suitable tillage technique can ensure most productive use of available hill torrent water in spate irrigated areas for improved crop productivity and profitability. During rabi season 2021-22, a field study on chickpea was undertaken in Vidor hill torrent command area of Dera Ghazi Khan Punjab, Pakistan. In this experiment three cultivars of chickpea viz Bittle-2016, Thal-2020 and Bhakhar-2011 were evaluated under spate irrigated conditions along with local cultivar (Farmer practice) for comparison. Tillage practices at the seedbed preparation stage evaluated were cultivator and rotavator as follows i.e. T_1= Two turns of cultivator (Farmer practice), T_2=Three turns of cultivator, T_3=Two turns of cultivator + one turn of rotavator, T_4= one turn of cultivator + one turn of rotavator. The experiment was conducted under randomized complete block design (RCBD) with factorial arrangement and treatments were replicated three times. Soil moisture was measured through gravimetric method and chickpea yield parameters were estimated as per standard procedures. The means were tested for significance using HSD Tuckey's test at 5 % level of probability. Results revealed that cultivars and tillage practices showed significant variations for tested parameters. In this experiment maximum soil moisture conservation, number of branches per plant, pods per plant, seeds per pod, seed yield (kg ha^{-1}) and harvest index (%) were observed from Farmer practice i.e. 2 turns of cultivator under local cultivar used. Moreover, comparatively similar results were revealed from the plots where 3 turns of cultivator was run and Thal-2020 cultivar was grown under the local conditions of Vidor hill torrent command area of Dera Ghazi Khan, Punjab, Pakistan. Plots where 2 turns cultivator was used, the maximum benefit cost ratio (BCR, 1.85) was observed from local cultivar (Farmer practice). Moreover, among newly tested cultivars, Thal-2020 showed encouraging results in terms of soil moisture contents, yield attributes with BCR 1.73 in plots where 2 turns cultivator was run. Under the prevailing agro normals of spate irrigated conditions of Vidor hill torrent command area, farmers should use 2 turns of cultivator with local cultivar. However, more research is needed to acclimatize the latest varieties of chickpea after adaptability trials.

Keywords: Benefit-cost ratio, Chickpea, tillage, cultivars, rotavator, soil moisture conservation, spate irrigation, Vidor hill torrent, yield.

INTRODUCTION

The soil moisture conserved from rainfall received before and during the growing season is the only source of water available for crops to grow until maturity in spate irrigated areas (Amin *et al*., 2019). Chickpea (*Cicer arietinum* L.) is the second most widely grown and largely consumed grain legume after beans in the Fabaceae family across the world (FAOSTAT, 2021). It is a key source of protein (16-20% in grain) in a vegetarian diet, and it has proven increasingly crucial in addressing the deficiency of protein and energy in the human diet (Prasad *et al.,* 2012). It also contains adequate carbohydrates, lipids, dietary fibre, vitamins, and minerals (Hirdyani, 2014). Globally, around 90% of

chickpea is grown under rainfed conditions, whereas 10% is grown under irrigated conditions (Anonymous, 2022a). The chickpea is grown on around 11 million ha, with global production of 14 million tonnes (Anonymous, 2022a). The national average production of chickpea in Pakistan (0.54 Mg ha^{-1}) is 40% lower than that (0.91 Mg ha^{-1}) in India (Muehlbauer and Sarker, 2017). Inadequate soil fertility, weed infestation and lack of soil moisture at critical times are the main reasons for low chickpea productivity (Jukanti *et al*., 2012). More than 95% of chickpea production in Pakistan comes from rainfed areas, where the genotypes produced have no evidence on their sensitivity to multiple moisture regimes, resulting in a lower yield (685 kg ha^{-1}) under rainfed environments (Yaqoob *et al*., 2013). In Pakistan, chickpea production is heavily reliant on rainfall throughout the growing season, as drought has a significant impact on plant yields (Naveed *et al*., 2016). Field management in spate irrigated areas may include but not limited to selection of suitable crops and cultivars having reduced water demands and can withstand dry periods and high temperatures, including leguminous crops in cropping systems to improve soil fertility, productivity and soil moisture holding ability (Mubeen, 2022).

Soil moisture and temperature are the primary factors that influence the sowing and emergence of chickpea (Soltani *et al*., 2006). Maximum seed emergence in dryland environments, necessitates a soil moisture content equivalent to field capacity (Anonymous, 2022b). The use of improved chickpea varieties plays a vital role in increased chickpea productivity (Chichaybelu *et al.,* 2018). The characteristics of high-quality seed can boost the chickpea yield up to 40 % (Mulat *et al*., 2022). The chickpea cultivars vary in their water use efficiency which subsequently effect the productivity of chickpea under rainfed conditions (Soltani and Sinclair, 2012). The chickpea planted under rainfed conditions encounters terminal drought due to progressively depleting soil moisture profile which subsequently effect crop yield (Kumar and Abbo, 2001).

For soil moisture conservation, role of tillage is important. Tillage is involved in creation of soil conditions favoring crop growth through rearranging soil particles (Bato *et al*., 2020). Tillage improves water penetration into the soil for more water retention to be subsequently utilized for crop growth (Khattak *et al*., 2018). Rotavator aids in improving crop yield through soil levelling, pulverization, weed management and soil moisture conservation (Mukesh *et al*., 2013). Levels of tillage and subsequent soil water availability decides chickpea stand at harvest (Dhar *et al*., 2008).

Breaking the compact plough layer through tillage speeds up root development resulting in improved crop yield (Roberto *et al*., 2017). Proper land preparation with various tillage operations, along with several other elements, plays an essential role in enhancing the output of rainfed land by moisture conservation (Farooq *et al*., 2011). Moreover, comparative study of cultivator and rotavator tillage frequency was needed for assessing the effect on moisture availability for larger period of time in the root zone and effect on crop yield especially in soils which have high clay proportion.

MATERIALS AND METHODS

A field trial was conducted in spate irrigated area of Vidor hill torrent, Dera Ghazi Khan, Punjab Pakistan. Seeds of chickpea cultivars (Bittle-2016, Thal-2020, Bhakkar-2011) were obtained from Arid Zone Research Institute (AZRI) Bhakkar Punjab, Pakistan. However, seeds of local cultivar was purchased from local market of hill torrent affected area of DG Khan for comparison. Seed were inoculated with rhizobium inoculant, collected from Department of Soil and Environmental Sciences, MNS University of Agriculture, Multan, Pakistan was carried out before sowing and was evaluated under different tillage treatments in vivo for hill torrent affected area of DG Khan Punjab, Pakistan. Seeds of chickpea cultivars were sown during the 2nd week of October, 2021 by using seed drill which was tractor mounted. 45 cm distance between rows and 23 cm distance between plants was maintained. Chickpea seed @ 90 kg ha^{-1} was used with a net plot size of 12ft × 50ft. Nitrogen @ 40 kg per hectare and phosphorus @ 28 kg per hectare were applied before crop sowing. Field trial was laid out in RCBD having factorial arrangement replicated three times. Rest of the practices were kept constant and uniform for all the treatments (Table 1).

Table 1. Treatments Employed During the Study.

Factor A: Cultivars	Factor B: Tillage Practices
C_1=Bittle-2016	T_1=Two turns of cultivator (Farmer practice)
C_2=Thal-2020	T_2=Three turns of cultivator
C_3=Bhakkar-2011	T_3=Two turns of cultivator + one turn of rotavator
C_4=Local cultivar (Farmer practice)	T_4= One turn of cultivator + one turn of rotavator

During the course of experiment soil moisture contents, functional nodules and yield parameters like plant height, branches and pods per plant, seeds per pod, 1000 seed weight, seed yield and harvest index were recorded. Soil moisture was measured through gravimetric methods. To see the physico-chemical properties of test soil, before sowing representative soil samples at 0-15 cm and 15-30 cm depth were collected and examined through standard practices. The test soil was found to be clayey in texture (Table 2). Moreover, mean temperature and rainfall data have been presented in Figure 1.

Table 2. Soil physico-chemical properties from spate irrigated chickpea fields under vidor hill torrent Dera Ghazi Khan, Punjab, Pakistan at the depth of 0-15 cm and 15-30 cm.

Characteristics	Unit	(0-15 cm)	(15-30 cm)
Extractable K	(ppm)	240	176
Available P	(ppm)	2.40	2.00
Organic Matter	(%)	0.41	0.28
SAR	-	2.33	2.11
EC	(mS cm^{-1})	0.58	0.60
pH	-	8.19	8.28
Saturation Percentage	(%)	63	66

Statistical analysis was done on the collected data and means of the treatments were compared with the help of HSD (Honest significant difference) Tuckey's test at 5 % probability level (Steel *et al*., 1997). Economic analysis was done by estimating benefit cost ratio and net profit (CIMMYT, 1988).

Economic Analysis

Net benefits and the benefit cost ratio (BCR) were calculated by using variable cost, total fixed cost, net benefit, and additional returns to check the benefit cost ratio of tested treatments. Comparative benefits of tested treatments were used for economic analysis. We calculated the production cost for chickpea cultivars based on prevailing market pricing for inputs, labor, and goods during the crop's growing season.

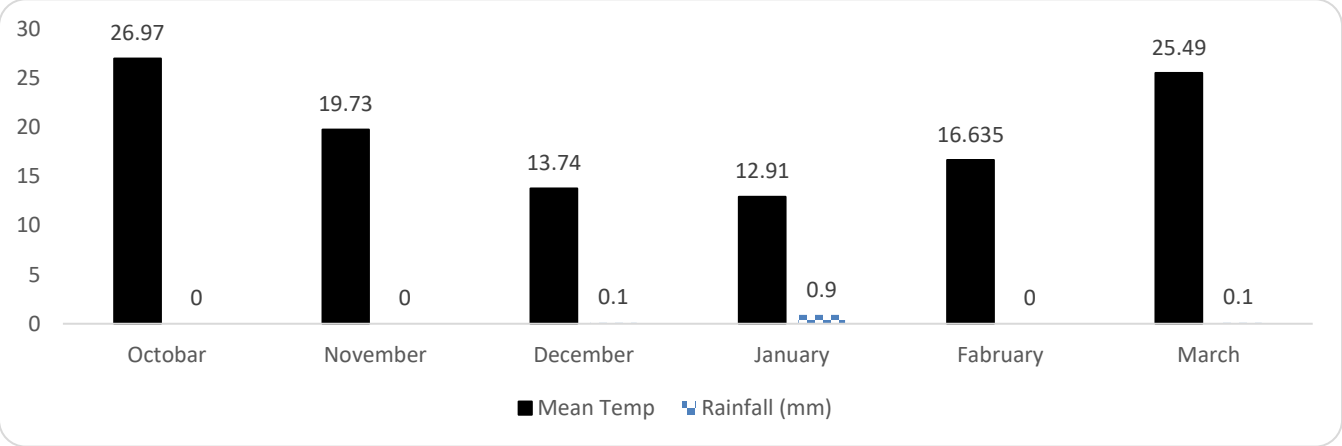

Figure 1. Mean temperature and rainfall during growing season 2021-22 at hill torrent affected crop fields of vidor hill torrent DG Khan Punjab Pakistan

RESULTS

Soil Moisture % at the Depth of 0-15 cm and 15-30 cm at 15 DAS, 60 DAS

The treatments employed showed substantial variation in terms of soil moisture conservation. Plots where Bittle-2016 cultivar was grown showed significantly maximum soil moisture availability under 2 turns cultivator use (Farmer practice) whereas minimum soil moisture was noted in plots where cultivator combined with rotavator were operated before sowing at both the soil depths i.e. 0-15 cm and 15-30 cm at 15 DAS. In all the tested varieties of chickpea, highest soil moisture availability was depicted in plots where cultivator was run 2 turns before crop sowing at seed bed preparation which was together with plots where cultivator was run three times and plots where 2 turns cultivator and 1 turn rotavator were run. Whereas 1 turn cultivator use + 1 turn rotavator run resulted in least soil moisture availability / conservation (Figure 2 and 3). Among the tested varieties, sequence of soil moisture availability observed is given below

Local cultivar > Thal-2020 > Bittle-2016 > Bhakkar-2011

Yield Related Parameters

Functional nodules and plant height (cm)

Interaction effect of cultivars and tillage techniques tested was significant hence discussed here. Significantly tallest plants of chickpea (42.00 cm) were observed in plots where bhakkar-2011 variety was grown receiving 2 turns cultivation (farmer practice) (Table 3). Whereas significantly shortest plants (28 cm) were obtained in plots where one turn cultivator was run together with one turn of rotavator where local cultivar was planted. Significantly, maximum plant height (42.00 cm) was noticed at the time of harvesting from the plots where Bhakhar-2011 cultivar was planted under 2 turns cultivator (Farmer practice). Whereas, cultivar Bhakhar-2011 showed significantly minimum plant height (31.00 cm) at the time of harvesting under the treatment cultivator together with rotavator which were practiced before sowing (Table 4). Local cultivar (Farmer practice) showed significantly maximum plant height (33.00 cm) at the time of harvesting under 2 turns of cultivator (Farmer practice) and significantly minimum plant height (28.00 cm) observed at the time of harvesting under cultivator together with rotavator. The plots associated with the cultivar Bittle-2016 showed significantly, maximum plant height at the time of harvesting (38.33 cm) under 2 turns cultivator (Farmer practice) and minimum plant height observed at harvest maturity (29.00 cm) under cultivator combined with rotavator which were practiced . The experimental units where the cultivar such as Thal-2020 was planted showed significantly maximum plant height at the time of harvesting (36.00 cm) under 2 turns cultivator and significantly minimum plant height noticed at harvest maturity (30.00 cm) under cultivator together with rotavator.

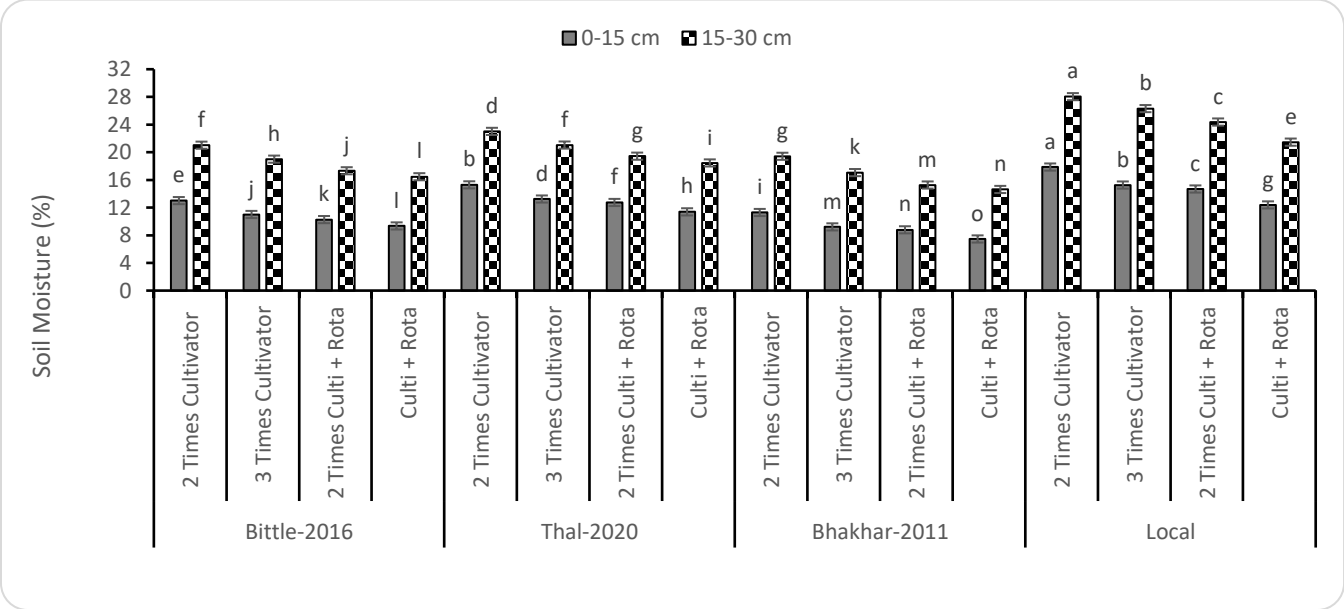

Figure 2. Rhizospheric moisture % at 15 DAS due to chickpea cultivars and tillage practices.
HSD Values 0-15 cm=4.15; 15-30 cm=2.03

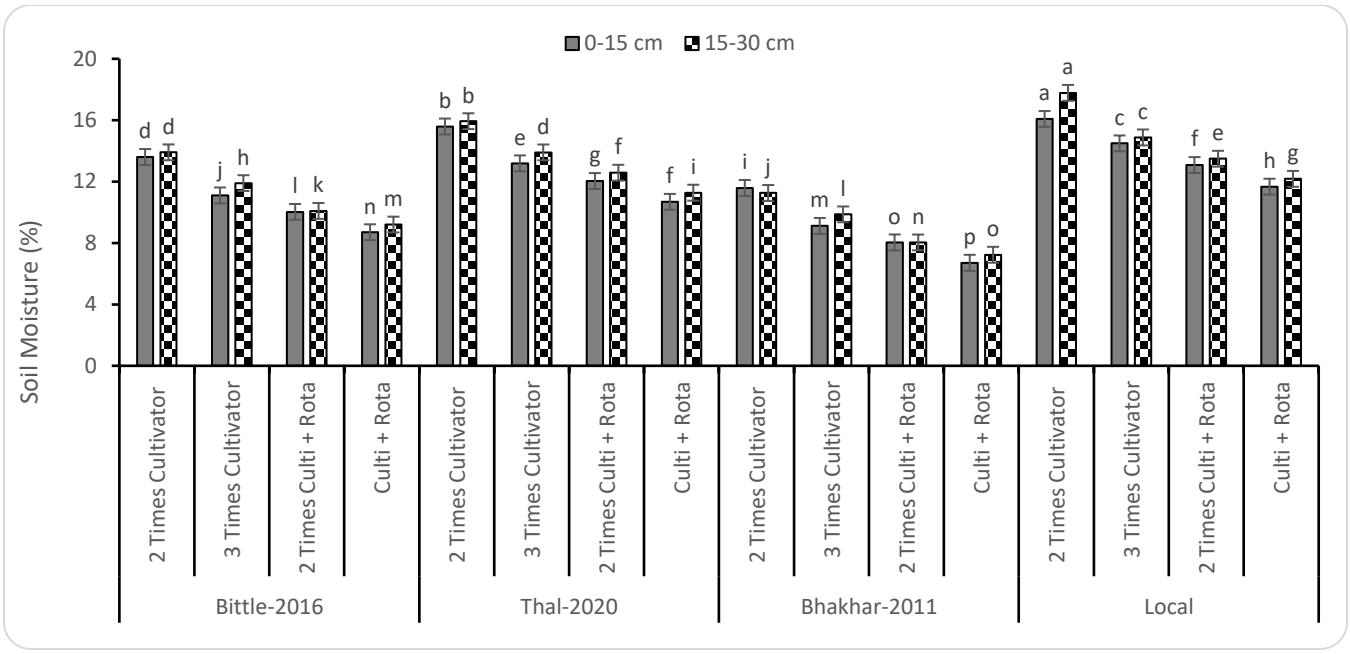

Figure 3. Rhizospheric moisture % at 60 DAS due to chickpea cultivars and tillage practices.
HSD Values: 0-15 cm=1.30, 15-30 cm=1.40

Table 3. Effect of chickpea cultivars and tillage practices on functional nodules grown in vidor hill torrent command areas DG Khan Punjab Pakistan.

Treatments	Two turns of cultivator	Three turns of cultivator	Two turns of cultivator + one turn of rotavator	One turn of Cultivator + one turn of rotavator	Mean
Bittle-2016	5.00 c	4.00 d	3.00 e	2.00 f	3.50 C
Thal-2020	6.00 b	5.00 c	5.00 c	4.00 d	5.00 B
Bhakhar-2011	4.00 d	3.00 e	2.00 f	1.33 g	2.58 D
Local cultivar	7.00 a	6.00 b	6.00 b	5.00 c	6.00 A
Mean	5.50 A	4.50 B	4.00 C	3.08 D	
HSD Values	Cultivar:0.49	Tillage:0.54	Interaction:0.76		

Means having same letters do not differ significantly at 5% probability level.

Branches per Plant

In the plots where Bittle-2016 cultivar was grown under 2 turns cultivator (Farmer practice) and cultivator combined with rotavator which were employed revealed significantly maximum (6.00) and minimum (4.50) number of branches per plant, respectively (Table 5). The cultivar Thal-2020 showed significantly maximum (7.00) and minimum (5.00) number of branches per plant under plots receiving 2 turns cultivator (Farmer practice) and cultivator together with rotavator, respectively. The plots grown with the cultivar Bhakhar-2011 represented significantly maximum number of branches per plant (5.00) under 2 turns cultivator (Farmer practice) and significantly minimum number of branches per plant (4.00) under cultivator combined with rotavator. The plots associated with the local cultivar (Farmer practice) showed significantly maximum number of branches per plant (7.60) where 2 turns cultivator (Farmer practice). Significantly, minimum number of branches per plant (5.75) were associated with plots where local cultivar (Farmer practice) was grown where cultivator together with rotavator were practiced. Tillage practices i.e. 3 turns of cultivator and 2 turns cultivator together with rotavator showed intermediate effects among all the tillage treatments employed regardless of cultivars. The

treatment 3 turns of cultivator performed better results as compared to 2 turns cultivator combined with rotavator and cultivator combined with rotavator in terms of branches per plant and held more closely with the farmer practice i.e. 2 turns cultivator. Consequently, maximum number of branches per plant were associated with the local cultivar and tillage practice 2 turns cultivator (Farmer practice). The minimum number of branches per plant were synchronized with the cultivar Bhakhar-2011 and tillage practice such as cultivator combined with rotavator.

The treatment 2 turns cultivator (Farmer practice) performed better in terms of branches per plant regardless of which cultivar was tested under this treatment. Similarly, the treatment local cultivar (Farmer practice) performed superior in terms of branches per plant regardless of which tillage practice was examined with this cultivar. The treatment cultivator together with rotavator performed poor in terms of branches per plant regardless of which cultivar was practiced under this treatment. Similarly, the plots where Bhakhar-2011 cultivar was grown showed poor results in terms of branches per plant regardless of tillage practice tested.

Table 4. Effect of chickpea cultivars and tillage practices on plant height (cm) grown in vidor hill torrent command areas DG Khan Punjab Pakistan

Treatments	Two turns of cultivator	Three turns of cultivator	Two turns of cultivator + one turn of rotavator	One turn of Cultivator + one turn of rotavator	Mean
Bittle-2016	38 c	36 d	33 f	29 j	34.00 B
Thal-2020	36 d	35 e	32 g	30 i	33.25 C
Bhakhar-2011	42 a	40 b	36 d	31 h	37.25 A
Local cultivar	33 f	31 h	29 j	28 k	30.25 D
Mean	37.25 A	35.50 B	32.50 C	29.50 D	
HSD Values	Cultivar:0.32	Tillage:0.32	Interaction:0.43		

Table 5. Effect of chickpea cultivars and tillage practices on branches per plant grown in vidor hill torrent command areas DG Khan Punjab Pakistan.

Treatments	Two turns of cultivator	Three turns of cultivator	Two turns of cultivator + one turn of rotavator	One turn of Cultivator + one turn of rotavator	Mean
Bittle-2016	6.00 e	5.50 h	5.00 i	4.50 j	5.25 C
Thal-2020	7.00 b	6.00 e	5.60 g	5.00 i	5.90 B
Bhakhar-2011	5.00 i	4.50 j	4.20 k	4.00 l	4.42 D
Local cultivar	7.60 a	6.40 c	6.10 d	5.75 f	6.46 A
Mean	6.40 A	5.60 B	5.22 C	4.81 D	
HSD Values	Cultivar:3.20	Tillage:3.20	Interaction:4.39		

Means having same letters do not differ significantly at 5% Probability level.

Pods per Plant

In the plots where Bittle-2016 cultivar was tested under 2 turns cultivator (Farmer practice) and cultivator combined with rotavator which were run revealed significantly maximum (34.33) and minimum (29.00) number of pods per plant, respectively (Table 6). The cultivar Thal-2020 showed significantly maximum (36.00) and minimum (30.00) number of pods per plant under 2 turns cultivator (Farmer practice) and cultivator together with rotavator, respectively. The plots associated with the cultivar Bhakhar-2011 represented significantly maximum number of pods per plant (30.00) under 2 turns cultivator (Farmer practice) and significantly minimum number of pods per plant (26.00) under cultivator combined with rotavator which were practiced.

The plots associated with the local cultivar (Farmer practice) showed significantly maximum number of pods

per plant (38.00) where 2 turns cultivator (Farmer practice). Significantly, minimum number of pods per plant (34.00) were obtained from local cultivar where cultivator together with rotavator were practiced. Consequently, maximum number of pods per plant were associated with the local cultivator and tillage practice 2 turns cultivator (Farmer practice). The minimum number of pods per plant were synchronized with the cultivar Bhakhar-2011 and tillage practice such as cultivator combined with rotavator.

The treatment 2 turns cultivator (Farmer practice) performed better in terms of pods per plant regardless of which cultivar was tested under this treatment. Similarly, the treatment local cultivar (Farmer practice) performed superior in terms of pods per plant regardless of which tillage practice was examined. The treatment cultivator together with rotavator performed poor in terms of pods per plant regardless of which cultivar was practiced under this treatment. Similarly, the treatment Bhakhar-2011 cultivar showed poor results regardless of which tillage practice was tested.

Table 6. Effect of chickpea cultivars and tillage practices on pods per plant grown in vidor hill torrent command areas DG Khan Punjab Pakistan.

Treatments	Two turns of cultivator	Three turns of cultivator	Two turns of cultivator + one turn of rotavator	One turn of Cultivator + one turn of rotavator	Mean
Bittle-2016	34.00 e	33.00 f	30.00 h	29.00 i	31.50 C
Thal-2020	36.00 c	35.00 d	31.00 g	30.00 h	33.00 B
Bhakhar-2011	30.00 h	29.00 i	27.00 j	26.00 k	28.00 D
Local cultivar	38.00 a	37.00 b	35.00 d	34.00 e	36.00 A
Mean	34.50 A	33.50 B	30.75 C	29.75 D	
HSD Values	Cultivar:0.69	Tillage:0.61	Interaction:1.74		

Seeds per Pod

Slight differences were observed from the plots with tested treatments were tested. The maximum number of seeds per pod obtained for local cultivar under 2 turns cultivator and 3 turns of cultivator use could not differ significantly from Thal-2020 under 2 turns of cultivator run fields (Table 7). However, fields receiving 2 turns cultivation + 1 turn rotavator; 1 turn cultivator run together with 1 turn rotavator run fields irrespective of tested varieties produced statistically similar number of seeds per pod of chickpea. Moreover, under three times cultivator run fields under variety grown Bittle-2016 and Bhakkar-2011 also produced statistically similar number of seeds per pod as above mentioned alongwith fields receiving 2 turns cultivator run in field where Bhakkar-2011 was run.

The plots associated with the cultivar Bittle-2016 showed maximum number of seeds per pod (1.66) where 2 turns cultivator (Farmer practice). While the other treatments remained non-significant with this cultivar. The plots where Thal-2020 cultivar was tested showed considerable variations as compared to the other cultivar under all the tillage treatments employed. Significantly, Thal-2020 cultivar showed maximum number of seeds per pod (2.00) from the plots where farmer practice was tested i.e. 2 turns of cultivator. The treatments 2 turns cultivator combined with rotavator and cultivator together with rotavator which were tested showed no difference regarding seeds per pod with the cultivar Thal-2020.

The plots with cultivar Bhakhar-2011 showed non-significant results under all the tillage treatments employed. The plots associated with the local cultivar (Farmer practice) showed slight differences among all the tillage treatments tested. The treatments 2 turns cultivator (Farmer practice) and 3 turns of cultivator showed no difference among each other regarding seeds per pod with the local cultivar (Farmer practice). Similarly, non-significant results were obtained from the treatments such as 2 turns of cultivator together with rotavator and cultivator combined with rotavator regarding seeds per pod with the local cultivar (Farmer practice).

Table 7. Effect of chickpea cultivars and tillage practices on seeds per pod grown in vidor hill torrent command areas DG Khan Punjab Pakistan.

Treatments	Two turns of cultivator	Three turns of cultivator	Two turns of cultivator + one turn of rotavator	One turn of Cultivator + one turn of rotavator	Mean
Bittle-2016	1.66 b	1.00 c	1.00 c	1.00 c	1.16 B
Thal-2020	2.00 a	1.50 b	1.00 c	1.00 c	1.37 A
Bhakhar-2011	1.00 c	1.00 c	1.00 c	1.00 c	1.00 C
Local cultivar	2.00 a	2.00 a	1.00 c	1.00 c	1.50 A
Mean	1.66 A	1.37 B	1.00 C	1.00 C	
HSD Values	Cultivar:0.16	Tillage:0.16	Interaction:0.21		

Means having same letters do not differ significantly at 5% probability level

1000 Seed Weight (g)

It was interesting to note that among the varieties tested, Thal-2020 produced heaviest grains in all tillage treatments tested. Moreover, grains obtained from bittle-2016 were also heavier compared with local cultivars (Table 8). However, Bhakkar-2011 grains were lighter even from the local cultivar tested. The plots associated with the cultivar Thal-2020 showed significantly maximum 1000 seed weight (398 g) under 2 turns cultivator (Farmer practice) which was practiced . Minimum 1000 seed weight of Thal-2020 (371 g) was observed under cultivator together with rotavator which was operated at time of land preparation. The plots where the cultivar such as Bittle-2016 was tested showed significantly maximum (348.33 g) and minimum (322 g) 1000 seed weight under 2 turns cultivator (Farmer practice) and cultivator combined with rotavator, respectively. The plots where local cultivar (Farmer practice) was practiced represented significantly maximum 1000 seed weight (298 g) under 2 turns cultivator (Farmer practice) and significantly minimum 1000 seed weight (275 g) was observed under cultivator combined with rotavator. The plots grown with the cultivar Bhakhar-2011 showed significantly maximum 1000 seed weight (248 g) under 2 turns cultivator (Farmer practice) which was implemented before sowing and significantly minimum 1000 seed weight (211 g) was noticed under cultivator together with rotavator.

The treatments 3 turns of cultivator and 2 turns of cultivator together with rotavator employed revealed intermediate effects among all the tillage treatments employed regardless of cultivars tested. Consequently, highest 1000 seed weight (398 g) was observed from the Thal-2020 cultivar under 2 turns cultivator (Farmer practice) and lowest 1000 seed weight (211 g) was noticed from Bhakhar-2011 cultivar under cultivator combined with rotavator. The treatment 2 turns cultivator (Farmer practice) performed better in terms of 1000 seed weight regardless of cultivar tested. Similarly, the treatment Thal-2020 cultivar performed superior in terms of 1000 seed weight regardless of tillage practice examined with this cultivar. The treatment cultivator together with rotavator performed poor in terms of 1000 seed weight regardless of cultivar practiced under this treatment. Similarly, the treatment Bhakhar-2011 cultivar showed poor results in terms of 1000 seed weight regardless of tillage practice tested.

Table 8. Effect of chickpea cultivars and tillage practices on 1000 seed weight (g) grown in vidor hill torrent command areas DG Khan Punjab Pakistan.

Treatments	Two turns of cultivator	Three turns of cultivator	Two turns of cultivator + one turn of rotavator	One turn of Cultivator + one turn of rotavator	Mean
Bittle-2016	348 e	337 f	331 g	322 h	334.58 B
Thal-2020	398 a	385 b	379 c	371 d	383.25 A
Bhakhar-2011	248 m	231 n	224 o	211 p	228.50 D
Local cultivar	298 i	281 j	269 k	275 l	276.25 C
Mean	323.00 A	308.50 B	300.75 C	290.25 D	
HSD Values	Cultivar:1.84	Tillage:1.84	Interaction: 2.13		

Seed Yield (kg ha^{-1})

Among the tillage treatments tested, plots where Bittle-2016 cultivar was tested under 2 turns cultivator (Farmer practice) and cultivator combined with rotavator which were run showed significantly maximum (725 kg) and minimum (665 kg) seed yield, respectively (Table 9). The cultivar such as Thal-2020 showed significantly maximum (775 kg) and minimum (715 kg) seed yield under 2 turns cultivator (Farmer practice) and cultivator together with rotavator, respectively. The plots associated with the cultivar such as Bhakhar-2011 represented significantly maximum seed yield (655 kg) under 2 turns cultivator (Farmer practice) and significantly minimum seed yield (595 kg) under cultivator combined with rotavator.

The plots associated with the local cultivar (Farmer practice) showed significantly maximum seed yield (855 kg) where 2 turns cultivator (Farmer practice). Significantly, minimum seed yield (795 kg) was associated from local cultivar (Farmer practice) where cultivator together with rotavator were practiced. Consequently, based on an overall interactive effect of tested varieties and tillage techniques maximum seed yield was associated with the local cultivar and tillage practice such as 2 turns cultivator (Farmer practice). Moreover, the minimum seed yield was obtained with the cultivar Bhakhar-2011 and tillage practice cultivator combined with rotavator. The treatment 2 turns cultivator (Farmer practice) performed better in terms of seed yield regardless of cultivar tested. Similarly, the treatment local cultivar (Farmer practice) performed superior in terms of seed yield regardless of the tillage practice examined. The treatment cultivator together with rotavator performed poor in terms of seed yield regardless of the cultivar tested. Similarly, the treatment Bhakhar-2011 cultivar showed poor results regardless of the tillage practice tested.

Table 9. Effect of chickpea cultivars and tillage practices on seed yield (kg ha^{-1}) grown in vidor hill torrent command areas DG Khan Punjab Pakistan.

Treatments	Two turns of cultivator	Three turns of cultivator	Two turns of cultivator + one turn of rotavator	One turn of Cultivator + one turn of rotavator	Mean
Bittle-2016	725 g	705 i	685 j	665 k	695.00 C
Thal-2020	775 e	755 f	725 g	715 h	742.50 B
Bhakhar-2011	655 l	635 m	615 n	595 o	625.00 D
Local cultivar	855 a	835 b	815 c	795 d	825.00 A
Mean	752.50 A	732.50 B	710.00 C	692.50 D	
HSD Values	Cultivar:1.98	Tillage:1.93	Interaction:2.29		

Harvest Index (%)

The substantial variations were shown from the plots where all the treatments were applied. Among the tested tillage treatments, plots where Bittle-2016 cultivar was tested under 2 turns cultivator (Farmer practice) and cultivator combined with rotavator showed significantly maximum (23.76 %) and minimum (22.92 %) harvest index respectively (Table 10). The cultivar Thal-2020 showed significantly maximum (27.18 %) harvest index under 2 turns cultivator (Farmer practice). The treatments Thal-2020 cultivar 2 turns cultivator together with rotavator and cultivator combined with rotavator showed non-significant results in terms of harvest index. The plots associated with the cultivar Bhakhar-2011 represented significantly maximum harvest index (20.14 %) under 2 turns cultivator (Farmer practice) and significantly minimum harvest index (19.18 %) under cultivator combined with rotavator which were practiced. The plots planted with the local cultivar (Farmer practice) showed significantly maximum harvest index (32.25 %) where 2 turns cultivator (Farmer practice) was practiced. Significantly, minimum harvest index (31.79 %) associated with local cultivar (Farmer practice) where cultivator together with rotavator were practiced. Consequently, on an overall interaction effect statistically maximum harvest index was associated with the local cultivar and tillage practice 2 turns cultivator (Farmer practice). Whereas, the minimum harvest index was obtained from the cultivar Bhakhar-2011 and tillage practice cultivator combined with rotavator. The treatment 2 turns cultivator (Farmer practice) performed better in terms of harvest index regardless of cultivar tested under this treatment. Similarly, the treatment local cultivar

(Farmer practice) performed superior in terms of harvest index regardless of tillage practice examined. Cultivator together with rotavator performed poor in terms of harvest index regardless of the cultivar tested. Similarly, the treatment Bhakhar-2011 cultivar showed poor results in terms of harvest index regardless of the tillage practice tested.

Table 10. Effect of chickpea cultivars and tillage practices on harvest index (%) grown in vidor hill torrent command areas DG Khan Punjab Pakistan.

Treatments	Two turns of cultivator	Three turns of cultivator	Two turns of cultivator + one turn of rotavator	One turn of Cultivator + one turn of rotavator	Mean
Bittle-2016	23.76 h	23.49 i	23.21 j	22.92 k	23.34 C
Thal-2020	27.18 e	26.95 f	26.35 g	26.47 g	26.74 B
Bhakhar-2011	20.14 l	19.43 m	19.51 n	19.18 o	19.67 D
Local cultivar	32.25 a	32.10 b	31.95 c	31.79 d	32.02 A
Mean	25.83 A	25.59 B	25.26 C	25.09 D	
HSD Values	Cultivar:8.74	Tillage:8.74	Interaction:0.11		

Means having the same letters do not differ significantly at 5% probability level.

DISCUSSION

Results obtained highlight the importance of variation in cultivars and tillage frequency regarding soil moisture conservation at 15 and 60 DAS. The farmer practice i.e. 2 turns of cultivator and local cultivar showed better results with the clayey soil in terms of soil moisture conservation and water use efficiency respectively which was reflected in the form of maximum availability of water in the rhizosphere. This might be due to well adapted characteristic of local cultivar to the particular climatic conditions as farmers are using local cultivar for decades in the spate irrigated areas of DG Khan Punjab Pakistan. Bhakhar-2011 cultivar and cultivator together with rotavator represented poor results regarding soil moisture conservation could be due to more water requirement of Bhakkar-2011. Moreover, practice of rotavator combined with cultivator might have resulted in creation of compact layer in clayey soil which could have reduced soil porosity and infiltration rate. Rotavator creates a surface sealing, blocking water infiltration and root proliferation in deeper soil layers which limits moisture availability in soil. The results are in accordance with the findings that conventional tillage practices had significantly higher moisture content then other tillage operations (Prem *et al*., 2017).

Taller plants of Bhakkar-2011 can be attributed to varietal characters over other tested varieties. 3 turns of cultivator also brought taller plants of Bhakkar-2011. These results are in accordance with the findings that 3 turns of cultivator significantly enhanced the plant height of maize plants (Anjum *et al*., 2019). The obtained results are however, contradictory to the outcomes of Banjara *et al*., 2017 who stated that zero and minimum tillage system increased height of chickpea plants. Such contradictions can be owing to varying water resources available, climatic and soil agro-normals, besides varietal and management factors.

Farmer practice i.e. 2 turns of cultivator and Thal-2020 cultivar performed supreme regarding 1000 seed weight. Heaviest grains obtained from Thal-2020 compared to other varieties including local cultivar can be attributed to inherent capacity of Thal-2020 to accumulate more photosynthates / assimilates in the economic part i.e. grain. It also gives hope to introduce promising cultivars after adaptability trials for more productivity from unit piece of land compared to traditional local cultivar which is being grown by farmers of the area since decades which could erode regarding its genetic potential in future under the backdrop of climate change. The possible reasons could be adaptability of the 2 turns of cultivator (Farmer practice) to the local conditions, light interception ability of the Thal-2020 cultivar which might have headed towards the maximum photosynthates accumulation to the sink. Our results are consistent with the findings that use of cultivator under rainfed conditions can significantly enhance the 1000 seed weight of legume crop (Khan *et al*., 2011). On the other side, poor results

obtained from Bhakhar-2011 cultivar and cultivator together with rotavator in terms of 1000 seed weight might be due to the reduced yielding potential of the cultivar Bhakhar-2011 under minimum soil moisture availability associated with cultivator combined with rotavator in spate irrigated conditions of vidor DG Khan Punjab Pakistan.

The highest number of functional nodules, number of branches per plant, pods per plant, seeds per pod, seed yield, harvest index observed from the farmer practice i.e. 2 turns of cultivator and local cultivar might be due to adaptability to the study area. Local cultivar (Farmer practice) had better potential regarding functional nodules formation as a result of strong roots microbial association in the soil environment. This might be due to its acclimatization to the local soil environment and same in the case of tillage practice i.e. 2 turns cultivator (Farmer practice). As the soil in the test field was clayey (Table 2) reflecting the increased soil porosity and infiltration with increase in cultivation frequency to 2 turns of cultivator as compared to the other tillage practices. The higher infiltration rate lead to better mineral uptake via soil solution. Moreover, lowest number of functional nodules associated with Bhakhar-2011 and cultivator together with rotavator could be due to poor roots bacterial association of the cultivar due to new introduction in the area with no acclimatization lacking adaptability time to show its potential and practice of rotavator could have enhanced the bulk density of clayey soil (Table 2). It might also be related to reduced availability of soil moisture during the growing season. These observations contradict the conclusions that the number of functional nodules rose dramatically with zero tillage system as compared to other tillage regimes (Quddus *et al*., 2020). Variations in climate, soil type, fertility, and varietal features may have contributed to these contradictory results.

Variation in tillage technique and cultivars was translated in number of branches per plant as well. The highest number of branches per plant observed from the farmer practice i.e. 2 turns cultivator and local cultivar might be due to their adaptability under the prevailing agro-normals of vidor hill torrent. Local cultivar (Farmer practice) had better potential regarding branches per plant formation as a result of maximum capturing of growth resources i.e. sunlight and carbon dioxide etc. This might be due to its better acclimatization to the local climate for decades of practice and same in the case of tillage practice i.e. 2 turns cultivator (Farmer practice). Moreover, lowest number of branches per plant associated with Bhakhar-2011 and cultivator together with rotavator can be explained by poor roots-bacterial association in Bhakkar-2011. Practice of rotavator would have crushed the upper soil layer into more fine dust particles which would have chocked the soil capillaries thereby reducing the water uptake from deeper layers. It might also be due to reduced availability of soil moisture during the growing season. However, these findings are contradictory to the outcomes of Quddus *et al*., 2020 who reported that number of branches were significantly increased with zero tillage system as compared to different tillage practices. The possible reasons of such contradictions could be the variations in tillage system used, climatic conditions, soil type, fertility, varying management practices and varietal traits.

The highest number of pods per plant observed from the Farmer practice i.e. 2 turns of cultivator and local cultivar might be due to adaptability of the local cultivar and tillage practice in the experimental area. Moreover, lowest number of pods per plant from Bhakhar-2011 and 1 turn each of cultivator and rotavator could be due to reduced yielding potential under hill torrent fed ecologies coupled with practice of rotavator which would have enhanced the bulk density of clayey soil. Bhakkar-2011 could have not responded well and may have not exhibited its genetic potential to low rhizospheric moisture in soil during the growing season, resulting in reduced growth resources uptake. It can be understandable as this variety was evaluated first time ever in hill torrent command areas of vidor DG Khan Punjab Pakistan under reduced soil moisture in hill torrent fed soils. These results are in line with the findings that conventional tillage operations i.e. use of cultivator significantly enhanced the pods per plant of legume crop (Khaemba *et al*., 2022). These findings are inconsistent with the results that use of cultivator can significantly increase the seeds per pod of cowpea crop and MB plough showed at par results with the cultivator (Khan *et al*., 2011). This could be due heterogeneity of crop type, tillage practices used and climatic conditions. The highest seed yield observed in farmer practice i.e. 2 turns of cultivator and local cultivar. These results are partially correlated with the findings that zero-tillage system significantly increased chickpea seed yield as compared to different tillage practices (Bimbraw, 2016).

Variations in climatic conditions, soil type, and varietal features may have contributed to contradictory results. The trend of results is in line with the findings that maximum harvest index was found with the use of conventional tillage practices through cultivator (Amrinder *et al*., 2019). Though these findings are in contrast from Ouji *et al.,* 2016 who stated that the testing of various varieties of chickpea does not influence its harvest index. This might be due to variations in available water system, cultivars tested and meteorological conditions.

CONCLUSION

Cultivation of local cultivar resulted in better soil moisture availability, maximum seed yield and highest BCR in the plots where 2 turns cultivation (Farmer practice) was carried out. Whereas among the new cultivars tested, Thal-2020 performed better than Bittle-2016 and Bhakhar-2011. Under the prevailing agro-normals farmers may use local cultivar and 2 turns of cultivator for better chickpea productivity. However, prospects for improvement have been observed for improving productivity of chickpea through acclimatization and standardization of improved chickpea cultivars in spate irrigated ecologies.

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Table 11. Total fixed cost (PKR) for chickpea production.

Sr.	Input operations	Unit	Quantity	Cost (Rs/Acre)	Cost (Rs / ha)
1	Land preparation	Hectare	1 turn of cultivator + 1 turn of rotavator	3000 + 4000 =7000	7000*2.47=17290
2	Seed	Kg ha^{-1}	90 kg	5465	5465*2.47=13500
3	Sowing	Hectare	Tractor drawn seed drill	3000	3000*2.47=7410
4	Fertilizers	Kg ha^{-1}	Urea (1.23) DAP (1.23)	-	2700*1.23=3321 10000*1.23=12300 3321+12300=15621
5	Harvesting	Labour/Day	3 Men	750	750*2.47=1852
6	Threshing	Labour/Day	2 Men	500	500*2.47=1235
7	Water diversion cost	Hectare	Tractor + Blade + Labour	3000 + 1200 + 1400=5600	5600*2.47=13832
8	Bund maintenance cost	Hectare	Tractor + Blade	2250 + 1200=3450	3450*2.47=8500
9	Land rent	Month	6	7500	7500*2.47=18525
	Total				97,765/-

Table 12. Benefit cost ratio (PKR) for chickpea production.

Sr. No	Treatments	G.Y (kg ha-1)	G.P (Rs. ha-1)	S.Y (kg ha-1)	S.P (Rs. ha-1)	T.P (Rs. ha-1)	T.F.C (Rs. ha-1)	V.C (Rs. ha-1)	T.C (Rs. ha-1)	N.B (Rs. ha-1)	B.C.R
1.	C_1T_1	725	159500	3050	122000	281500	97765	17550	115315	166185	1.69
2.	C_1T_2	705	155100	3000	120000	275100	97765	18090	115855	159245	1.62
3.	C_1T_3	685	150700	2950	118000	268700	97765	18360	116125	152575	1.56
4.	C_1T_4	665	146300	2900	116000	262300	97765	17820	115585	146715	1.50
5.	C_2T_1	775	170500	2850	114000	284500	97765	16650	114415	170085	1.73
6.	C_2T_2	755	166100	2800	112000	278100	97765	17190	114955	163145	1.66

7.	C_2T_3	725	159500	2750	110000	269500	97765	17460	115225	154275	1.57
8.	C_2T_4	715	157300	2700	108000	265300	97765	16920	114685	150615	1.54
9.	C_3T_1	655	144100	3250	130000	274100	97765	18450	116215	157885	1.61
10.	C_3T_2	635	139700	3200	128000	267700	97765	18990	116755	150945	1.54
11.	C_3T_3	615	135300	3150	126000	261300	97765	19260	117025	144275	1.47
12.	C_3T_4	595	130900	3100	124000	254900	97765	18720	116485	138415	1.41
13.	C_4T_1	855	188100	2650	106000	294100	97765	14850	112615	181485	1.85
14.	C_4T_2	835	183700	2600	104000	287700	97765	15390	113155	174545	1.78
15.	C_4T_3	815	179300	2550	102000	281300	97765	15660	113425	167875	1.71
16.	C_4T_4	795	174900	2500	100000	274900	97765	15120	112885	162015	1.65

C1T1: Bittle-2016 + 2 turns of cultivator; **C1T2:** Bittle-2016 + 3 turns of cultivator; **C1T3:** Bittle-2016 + 2 turns of cultivator + 1 turn of rotavator; **C1T4:** Bittle-2016 + 1 turn of cultivator and 1 turn of rotavator; **C2T1:** Thal-2020 + 2 turns of cultivator

C2T2: Thal-2020+ 3 turns of cultivator; **C2T3:**Thal-2020 + 2 turns of cultivator and 1 turn of rotavator; **C2T4:** Thal-2020 + 1 turn of cultivator and 1 turn of rotavator; **C3T1:** Bhakkar-2011 **+** 2 turns of cultivator; **C3T2:** Bhakkar-2011 + 3 turns of cultivator

C3T3: Bhakkar-2011 + 2 turns of cultivator and 1 turn of rotavator; **C3T4:** Bhakkar-2011 + 1 turn of cultivator and 1 turn of rotavator; **C4T1:** Local cultivar + 2 turns of cultivator; **C4T2:** Local cultivar + 3 turns of cultivator; **C4T3:** Local cultivar + 2 turns of cultivator + 1 turn of rotavator; **C4T4:** Local cultivar + 1 turn of cultivator and 1 turn of rotavator

G.Y: Grain Yield; **G.P:** Grain Price; **S.Y:** Straw Yield; **S.P:** Straw Price; **T.P:** Total Price; **T.F.C:** Total Fixed Cost **V.C:** Variable Cost**; N.B:** Net Benefit ; **B.C.R:** Benefit Cost Ratio and **T.C:** Total Cost

Note: 1 USD: 163 PKR

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