Int. J. Agr. Ext. 11 (03) 2023. 307-318

DOI: 10.33687/ijae.011.03.4954

Available Online at EScience Press

International Journal of Agricultural Extension

ISSN: 2311-6110 (Online), 2311-8547 (Print)

https://esciencepress.net/journals/IJAE

TILLAGE PRACTICES AFFECT SOIL MOISTURE CONSERVATION AND PRODUCTIVITY OF ARUGULA (ERUCA SATIVA L.) IN HILL TORRENT AFFECTED AREAS OF PUNJAB

[a]Faheem Nawaz, [a]Khuram Mubeen*, [a]Rao M. Ikram, [b]Muhammad U. Jamshaid, [a]Mudassir Aziz, [c]Fahid Ehsan, [d]Abdul Khaliq, [a]Sohail Irshad

[a] *Department of Agronomy, MNS University of Agriculture Multan*

[b] *Department of Soil and Environmental Sciences, MNS University of Agriculture Multan, Pakistan.*

[c] *Senior Scientist, (Agronomy), Agronomic Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan.*

[d] *Soil and Water Testing Laboratory, Kotla Ahmad Road Rajanpur, Pakistan.*

ARTICLE INFO

Article History

Received: July 20,2023

Revised: November 10,2023

Accepted: December 12,2023

Keywords

Arugula

Cultivator

Rotavator

Soil moisture

Spate irrigation

Vidor hill torrent

Yield

ABSTRACT

The use of the right tillage technique can help promote higher earnings, crop productivity, soil improvement, and the most effective use of available water resources. The field experiment was conducted in the Vidor Hill torrent command area of Dera Ghazi Khan Punjab, Pakistan during the winter of 2021-22. In this experiment, tillage treatments including cultivator and rotavator were assessed as follows i.e. T1= 2-times cultivator (farmer practice), T2=3-times cultivator, T3=2-times cultivator + rotavator, T4= cultivator + rotavator. The trial was laid out under RCBD and treatments in the experiment were repeated thrice. Soil moisture % and yield parameters including number of siliquae plant-1, 1000 seed weight (g), biological yield (kg ha^{-1}), seed yield (kg ha^{-1}) and harvest index (%) were estimated as per standard procedures. The means were tested for significance using HSD Tuckey's test at a 5 % probability level. Results showed that the highest soil moisture conservation, number of siliquae per plant (106.41), number of seeds per siliquae (21.39), seed yield (570 kg ha^{-1}) and harvest index (32.92%) were noticed from the farmer practice i.e. 2 times cultivator. Whereas, statistically comparative results were also observed from the treatment such as 2 times cultivator combined with rotavator at Vidor hill torrent command area of Dera Ghazi Khan Punjab, Pakistan. Under 2 times cultivator (Farmer Practice), the benefit-cost ratio (1.41) was highest as compared to the benefit-cost ratio (1.28) observed from 2 times cultivator accompanied with a rotavator. Among newly tested tillage treatments 2 times cultivator followed by rotavator showed promising results in hill torrents-based arugula production. Hence under the prevailing agro normals, farmers of hill torrent-based production systems may use 2 times cultivator for land preparation for better arugula productivity in hill torrent-based crop production systems.

Corresponding Author: Khuram Mubeen

Email: khurram.mubeen@mnsuam.edu.pk

INTRODUCTION

The second major source of irrigation in Pakistan, after canal water, is a spate irrigation system that uses seasonal floods, which are a source of water from hill torrents (Ahmad et al., 2016). Rainfall irregularity may have an impact on unpredictable spate irrigation during the time of sowing (Javed et al., 2007). Rainwater conservation is critical for successful rainfed agricultural production in spate irrigated areas (Barron *et al*., 2003). Under spate irrigated conditions, the soil moisture conservation practices encourage infiltration, moisture storage and subsequent increase in crop yield (FAO, 2022a). In Pakistan, there are around 2.6 million acres of land under spate irrigation, and between 9 and 13 million people are directly dependent on it (Steenbergen and Mehari, 2008). The current area under spate irrigation varies between 0.34 and 1.28 million hectares from dry to wet years respectively, with the capacity to grow about 7 million hectares (Mubeen, 2022). Growing oilseeds in spate irrigated areas has shown to be productive as they require less water and do better even during dry seasons (PARC 2022b). Arugula has rapid vegetative growth rate, short duration cycle and high yield per unit area (Oliveira et al., 2013). Its production period begins with the appearance of seedlings and lasts until floral initiation, which corresponds to the economically viable production phase (Jardina *et al*., 2017). Traditional oil seed crops are important in Pakistan having (44-46%) of oil and (38-40%) of protein with complete profile of amino acids (PARC, 2022b).

The planting time of Brassica species vary significantly under spate irrigated conditions in south Punjab, from mid-October to mid-November (PARC, 2022b). Tillage is an important aspect of agricultural production technology because it affects soil processes, features, and crop growth, all of which influence agricultural sustainability (Khursheed et al., 2019). The success of on-farm soil water conservation, is determined by a number of soil parameters, including bulk density, porosity, soil surface sealing and crusting, surface roughness, hardpans, hydraulic conductivity, and infiltration rates (Strudley et al., 2008). The use of proper tillage method can encourage higher profits, crop production, soil improvement, and the most efficient use of water resources because tillage has a direct impact on soil and water quality (Hanna and Al-Kaisi, 2009). Conservational tillage operations mitigate the adverse effects of conventional tillage operations on soil and crop while they provide yield similar to that of conventional tillage system (Grabowski et al., 2014). Tillage techniques that conserve soil moisture are critical for plant growth in arid and semi-arid environments (Blanco et al., 2017). Deep tillage operations in coarse textured soil helped in reducing soil compaction, strength, improving root distribution and penetration which helped in maximum water uptake from soil (Ekin et al., 2005).

The soil moisture limitations are the major constraints for agricultural crop production. Summer crops are reliant on rainwater, but winter crops are reliant on moisture conserved in the soil (Dhar et al., 2008). Arugula is a deep-rooted crop. Tillage through cultivator and rotavator will affect differentially soil moisture conservation and subsequently crop at lateral growth stages. Hence a need was felt to monitor the soil moisture through use of cultivator and rotavator at the time of land preparation with subsequent impact on arugula productivity in spate irrigated ecologies of vidor hill torrent command area Dera ghazi Khan Punjab Pakistan.

MATERIALS AND METHODS

The field experiment was conducted at Vidor hill torrent command area of Dera Ghazi Khan Punjab, Pakistan that lies between latitude 30.920° N to 30.782°N and longitude 70.978°E to 70.844°E with altitude of about 219 m above mean sea level. The seeds of arugula used for cultivation were collected from local market of spate irrigated area, Dera Ghazi Khan. Sowing was done during the Second week of October, 2021 through tractor drawn seed drill. In this experiment, row to row and plant to plant distance was kept 45 cm and 15 cm, respectively. Seed rate used for arugula cultivation was 5 kg ha^{-1} and the net plot size in field was 10ft × 50ft. At the time of sowing, the amount of nitrogen and phosphorus was applied at the rate of 16 kg and 11.5 kg per acre respectively. The design used for experiment was Randomized complete block (RCBD) and the treatments were repeated thrice. All the other agronomic procedures were kept normal and uniform for all the treatments. To assess variation in soil moisture and productivity of arugula, different tillage practices were evaluated in field conditions of spate irrigated area, Dera Ghazi Khan.

Tillage practices treatments evaluated at the time of seedbed preparation included 2 times cultivator use i.e. farmer practice; 3-time cultivator use, 2 time cultivator use followed by 1 time rotavator; use of 1 time cultivator and rotavator. Data were collected for soil moisture and agronomic parameters including plant height (cm), siliquae $plant^{-1}$, siliquae's length (cm), number of seeds $siliquae^{-1}$, biological yield (kg ha^{-1}), seed yield (kg ha^{-1}), harvest index (%) of arugula crop. The soil moisture readings were taken out through digital soil moisture meter during the growing season.

Before sowing, composite soil samples were taken from depth of 0-6 inches and 6-12 inches to investigate the physico-chemical parameters of the soil. The obtained data were analyzed, and the means of the treatments were compared by using HSD (Honest significant difference) Tukey's test at 5% probability level (Steel *et al*., 1997). The benefit cost ratio and net profit were calculated as part of the economic analysis (CIMMYT, 1988) (Figure 1; Table 1).

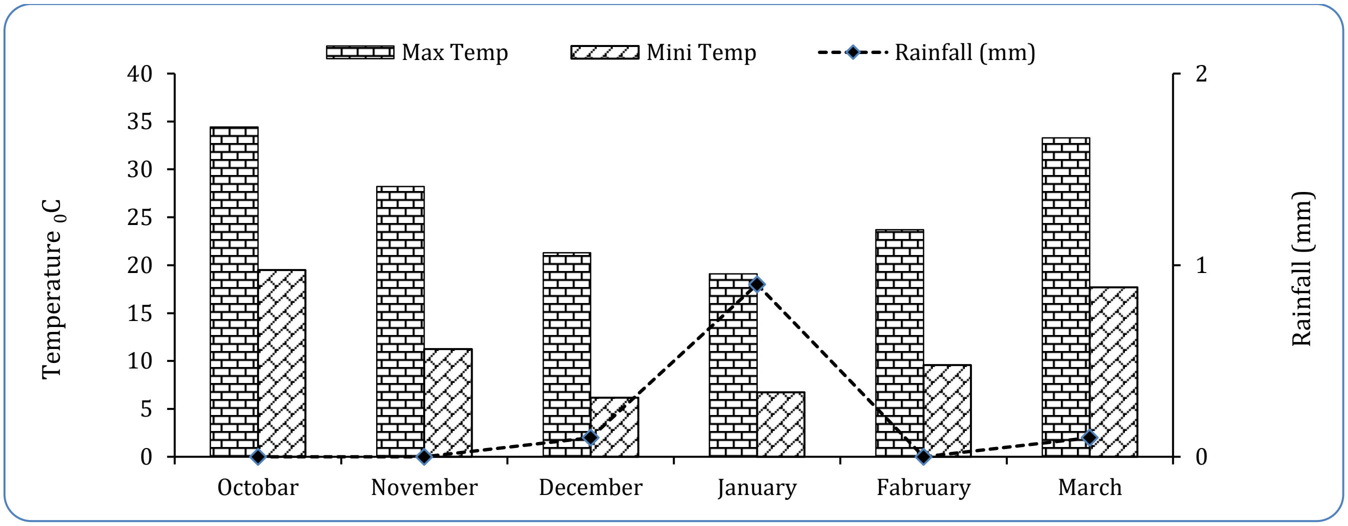


Figure 1. Rainfall, maximum and minimum temperature during course of the experiments 2021-22 in Vidor hill torrent command area Dera Ghazi Khan Punjab Pakistan.

Table 1. Soil physico-chemical properties at the depth of 0-15 cm and 15-30 cm of vidor hill torrent command area soil Dera Ghazi Khan Punjab Pakistan.

Characteristics	Unit	(0-15 cm)	(15-30 cm)
Texture	-	Clayey	Clayey
Gypsum Requirement	(tons $acre^{-1}$)	-	-
Extractable K	(mg kg^{-1} soil)	242	178
Available P	(mg kg^{-1} soil)	2.38	2.10
Organic Matter	(%)	0.42	0.26
SAR	-	2.31	2.14
EC	(mS cm^{-1})	0.56	0.62
pH	-	8.12	8.26
Saturation Percentage	(%)	62	65

RESULTS

Soil Moisture %

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

There was significant difference observed from plots under all the treatments employed in terms of soil moisture conservation. Significantly, maximum soil moisture noticed at both the depths i.e. 0-15 cm and 15-30 cm from the plots where 2 times cultivator (Farmer Practice) was run at the time of land preparation. Significantly, minimum soil moisture was observed from the plots where 3 times cultivator was practiced at the time of land preparation from both the depths. The plots where 2 times cultivator followed by rotavator were run before sowing showed significantly maximum soil moisture at both the depths when compared with the treatment such as 3 times cultivator. The plots where the treatment such as cultivator followed by rotavator was employed at the time of land preparation showed statistically minimum soil moisture when compared with the treatment such as 2 times cultivator (Farmer Practice). The treatments such as 2 times cultivator accompanied with rotavator and cultivator followed by rotavator showed slight difference in terms of soil moisture conservation and were the intermediate between 3 times cultivator and 2 times cultivator (Farmer Practice) (Figure 1, 2, 3).

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

There was significant difference observed from plots under all the treatments employed in terms of soil moisture conservation. Significantly, maximum soil moisture noticed at both the depths i.e. 0-15 cm and 15-30 cm from the plots where 2 times cultivator (Farmer Practice) was run at the time of land preparation. Significantly, minimum soil moisture was observed from the plots where 3 times cultivator was practiced at the time of land preparation from both the depths. The plots where 2 times cultivator followed by rotavator were run before sowing showed significantly maximum soil moisture at both the depths when compared with the treatment such as 3 times cultivator. The plots where the treatment such as cultivator followed by rotavator was employed at the time of land preparation showed statistically minimum soil moisture when compared with the treatment such as 2 times cultivator (Farmer Practice). The treatments such as 2 times cultivator accompanied with rotavator and cultivator followed by rotavator showed slight difference in terms of soil moisture conservation and were the intermediate between 3 times cultivator and 2 times cultivator (Farmer Practice).

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

There was significant difference observed from plots under all the treatments employed in terms of soil moisture conservation. Moreover, slightly rainfall was observed before taking this reading which could be the reason for highest soil moisture presence at the depth of 0-15 cm. Significantly, maximum soil moisture observed at both the depths i.e. 0-15 cm 15-30 cm from the plots where the treatment such as 2 times cultivator (Farmer Practice) was employed at the time of land preparation. Significantly, lowest soil moisture at both the depths was noticed from the experimental units where the treatment such as 3 times cultivator was run at the time of land preparation. The treatment such as 2 times cultivator accompanied with rotavator tested at the time of land preparation showed significantly maximum soil moisture when compared with the treatment such as 3 times cultivator (T_2). The plots where the treatment such as cultivator followed by rotavator was operated at the time of land preparation showed significantly minimum soil moisture at both the depths as compared with the treatment such as 2 times cultivator (Farmer Practice). The plots associated with the treatment such as 2 times cultivator followed by rotavator showed significantly maximum soil moisture at both the depths when compared with the treatment such as cultivator accompanied with rotavator and minimum soil moisture as compared to the farmer practice i.e. 2 times cultivator.

Agronomic Parameters

Plant Height (cm)

Taramira (arugula) shows significantly greater plant height (104.46 cm) in the plots where the 3 times cultivator was run. Significantly lowest plant height (83.18 cm) was noticed at the plots where the 2 times cultivator was assessed before crop seeding at the time of land preparation. The plot where the 2 times frequency of cultivator and rotavator combined were employed showed significantly smaller plant height (92.24) as compared to the 3 times frequency of cultivator. While the treatment such as cultivator accompanied with rotavator showed significantly greater plant height (94.38) when compared with plant height from plots where 2 times frequency of cultivator was run and 2 times cultivator with rotavator. Statistical results showed that lower plant height was observed at the field plots where 2 times frequency of cultivator was tested.

Siliquae per Plant

Number of siliquae of Taramira (arugula) crop resulted in significantly differences among all the treatments employed. The maximum number siliquae per plant (106.41) was observed from the plots where 2 times cultivator was checked. Significantly minimum number of siliquae per plant (77.60) was noticed under 3 times cultivator from the experimental units. The treatment such as cultivator followed by rotavator showed significantly lower number of siliquae per plant (82.80) compared with the 2 times cultivator followed by rotavator. The treatment such as 2 times cultivator accompanied with rotavator resulted maximum number of siliquae (90.49) after the farmer practice.

Seeds per Siliquae

The plots where the 2 times cultivator was tested showed significantly maximum number of seeds per siliquae (21.39). The treatment such as 3 times cultivator resulted significantly lower number of seeds per siliquae (14.20) where it was tested. The experimental units where the treatment such as 2 times cultivator accompanied with rotavator was assessed showed statistical similar revealed maximum number of seeds per siliquae (19.20) when compared with the farmer practice. While the treatment such as cultivator followed by rotavator resulted statistically same number of seeds per siliquae when compared with the treatment such as 3 times cultivator.

Length of Siliquae (cm)

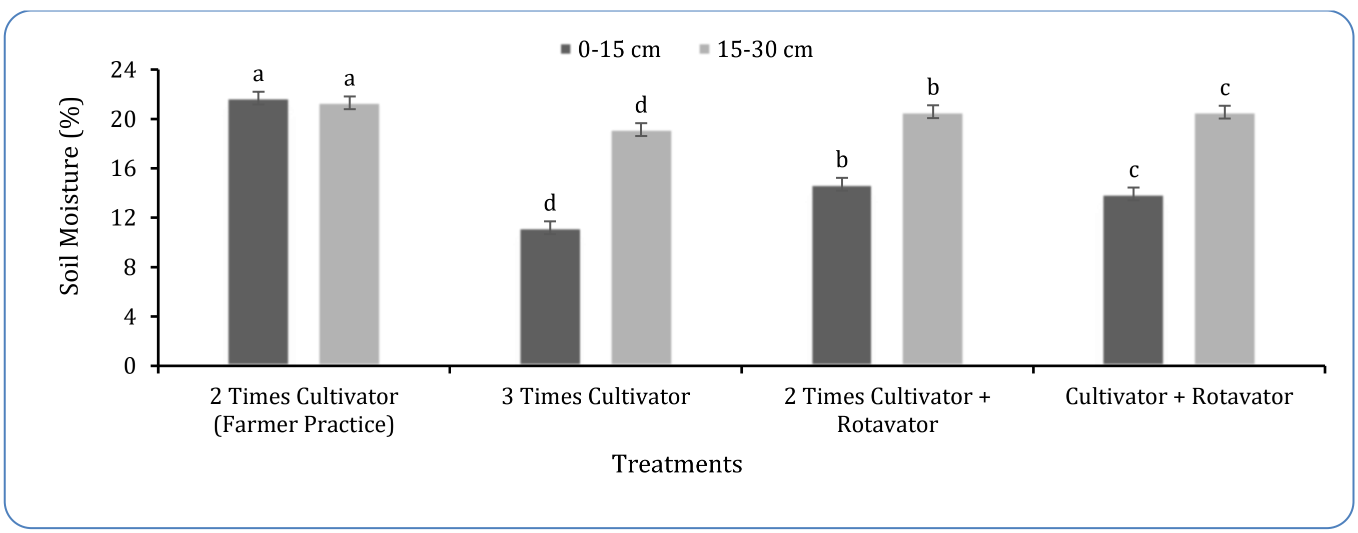
Arugula Plants were resulted significantly no difference in length of siliquae observed from plots where all the treatments were employed. However, the maximum siliquae length (2.88 cm) noticed from plots where the treatment such as 2 times cultivator (Farmer Practice) was tested. Significantly, minimum siliquae length (4.21 cm) was observed from plots where the treatment such as 3 times cultivator was employed. The obtained result from the plots where 2 times cultivator was run could be due to maximum availability of resources i.e. soil moisture and nutrient availability.

1000 Seed Weight (g)

There was no significantly statistical difference observed from the plots where all the treatments were employed. However, the maximum 1000 seed weight (4.83 g) noticed from plots where the treatment such as 2 times cultivator (Farmer Practice) was tested. Significantly, lowest 1000 seed weight (4.21g) was observed from plots where the treatment such as 3 times cultivator was employed. These findings are in contrast with the observations that arugula planted in sole strip showed significantly maximum 1000 seed weight under spate irrigated conditions (Amin et al., 2019). This might be due use of different planting techniques, soil type, climatic conditions and adequate amount of rainfall received.

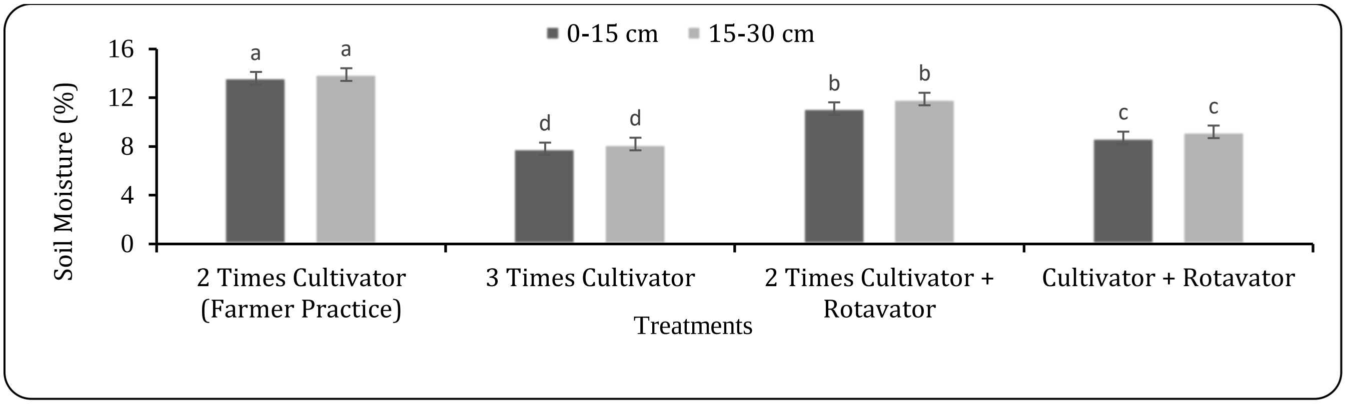
Biological Yield (kg ha^{-1})

Biological yield of taramira (arugula) crop resulted in significantly differences among all the treatments tested. The maximum biological yield (1856 kg ha^{-1}) was observed from the plots where the 3 times cultivator was employed. Significantly lowest biological yield (1729 kg ha^{-1}) was noticed under 2 times cultivator (Farmer Practice) from the plots.



HSD Values: 0-15 cm=1.63 15-30 cm=1.41

Figure 2. Soil moisture % at 15 DAS as influenced by tillage practices in spate irrigated arugula fields of Dera Ghazi Khan Punjab Pakistan.



HSD Values: 0-15 cm=1.94 15-30 cm=1.82

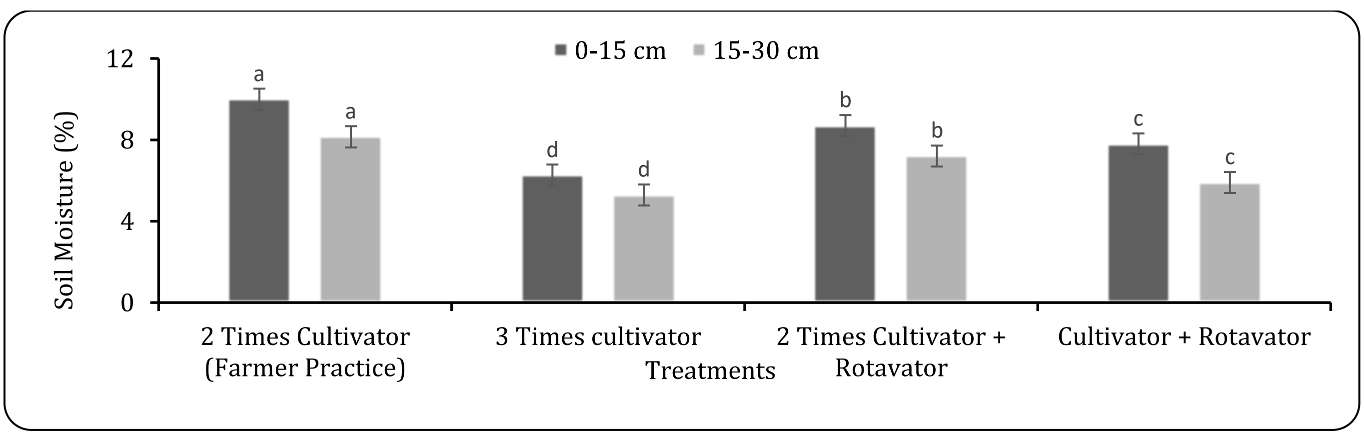
Figure 3. Soil moisture % at 60 DAS as influenced by tillage practices in spate irrigated arugula fields of Dera Ghazi Khan Punjab Pakistan.

The treatment such as 2 times cultivator followed by rotavator showed significantly maximum biological yield (1765 kg ha^{-1}) when compared with the treatment such as treatment 2 times cultivator (Farmer Practice). The treatment such as cultivator accompanied with rotavator resulted maximum biological yield (1803 kg ha^{-1}) when compared with the treatment such as 2 times cultivator followed by rotavator. The treatments such as cultivator accompanied with rotavator and 2 times cultivator with rotavator showed statistically closer results when compared with the treatment such as 3 times cultivator.

Seed Yield (kg ha^{-1})

Taramira (arugula) plants resulted significantly differ in their response to tillage treatments in terms of seed yield. The maximum seed yield (570 kg ha^{-1}) was observed from the plots where 2 times cultivator (Farmer Practice) was employed at the time of land preparation. Significantly, lowest seed yield (460 kg ha^{-1}) was noticed from the experimental units where 3 times cultivator was tested before sowing. The treatment such as 2 times cultivator followed by rotavator resulted significantly closer seed yield (515 kg ha^{-1}) when compared with the treatment such as 2 times cultivator (Farmer Practice).

The plots where the treatment such as cultivator accompanied with rotavator tested at the time of land preparation, showed slightly maximum seed yield (482 kg ha^{-1}) as compared to the treatment such as 3 times cultivator. The treatments such as 2 times cultivator with rotavator and cultivator followed by rotavator showed statistically intermediate results when compared with 2 times cultivator (Farmer Practice) and 3 times cultivator.



HSD Values: 0-15 cm=1.63 15-30 cm=2.05

Figure 4. Soil moisture % at 156 DAS as influenced by tillage practices in spate irrigated arugula fields of Dera Ghazi Khan Punjab Pakistan.

Harvest Index (%)

The response of taramira (arugula) plants to tillage treatments differed significantly in terms of harvest index. The maximum harvest index (32.92 %) was obtained from the plots where 2 times cultivator (Farmer Practice) was tested at the time of land preparation. Significantly, minimum harvest (24.74 %) was noticed from the plots where 3 times cultivator was employed before sowing. The treatment such as 2 times cultivator accompanied with rotavator resulted significantly closer harvest index (29.14 %) when compared with the treatment such as 2 times cultivator (Farmer Practice).

The plots where the treatment such as cultivator accompanied with rotavator employed at the time of land preparation, showed slightly maximum harvest index (26.69 %) as compared to the treatment such as 3 times cultivator. The treatments such as 2 times cultivator with rotavator and cultivator followed by rotavator showed statistically intermediate results when compared with 2 times cultivator (Farmer Practice) and 3 times cultivator.

Table 2. Effect of tillage practices on plant height (cm), siliquae per plant and seeds per siliquae of arugula in spate irrigated fields of vidor hill torrent command area Dera Ghazi Khan Punjab Pakistan.

Treatments	Plant Height (cm)	Siliquae per Plant	Seeds per Siliquae
2 Times Cultivator (Farmer Practice)	83.18 d	106.41 a	21.39 a
3 Times Cultivator	104.46 a	77.60 d	14.20 c
2 Times Cultivator + Rotavator	92.24 c	90.49 b	19.20 ab
Cultivator + Rotavator	94.38 b	82.80 c	16.40 bc
HSD Values	0.24	0.24	3.29

Table 3. Effect of tillage practices on siliquae's length (cm), 1000 seed weight (g) and biological yield (kg ha^{-1}) of arugula in spate irrigated fields of vidor hill torrent command area Dera Ghazi Khan Punjab Pakistan.

Treatments	Siliquae's Length (cm)	1000 Seed Weight (g)	Biological Yield (kg ha^{-1})
2 Times Cultivator (Farmer Practice)	2.88 *NS	4.83 *NS	1729 d
3 Times Cultivator	2.38	4.21	1856 a
2 Times Cultivator + Rotavator	2.66	4.51	1765 c
Cultivator + Rotavator	2.56	4.41	1803 b
HSD Values	1.62	1.64	18.00

*NS: Non-Significant

Table 4. Effect of tillage practices on seed yield (kg ha^{-1}) and harvest index (%) of arugula in spate irrigated fields of vidor hill torrent command area Dera Ghazi Khan Punjab Pakistan.

Treatments	Seed Yield (kg ha^{-1})	Harvest Index (%)
2 Times Cultivator (Farmer Practice)	570 a	32.92 a
3 Times Cultivator	460 d	24.74 d
2 Times Cultivator + Rotavator	515 b	29.14 b
Cultivator + Rotavator	482 c	26.69 c
HSD Values	0.81	0.12

DISCUSSION

The trend in results obtained highlight the importance of variation in tillage frequency regarding soil moisture conservation at 15 DAS. As the soil in the trial's area was clayey reflecting the increased soil porosity and infiltration rate at both the depths i.e. 0-15 cm and 15-30 cm with increase in cultivation frequency to 2 times cultivator (Farmer Practice) likely because of its adaptability in the studied area. The minimum soil moisture was accompanied with 3 times cultivator which might be due to minimum soil porosity and infiltration rate at both the depths. The pattern of results associated with the treatments such as 2 times cultivator followed by rotavator and cultivator accompanied with rotavator might be due to practice of rotavator which could have resulted in sealing of soil surface, reduced soil porosity and infiltration rate as the soil under studied area was clayey. These results are in line with the findings of Li et al. (2020) who also stated that various tillage treatments enhanced soil moisture conservation under the arid climate.

The results obtained highlight the importance of variation in tillage frequency regarding soil moisture conservation at 60 DAS. As the soil in the trial's area was clayey reflecting the increased soil porosity at both the depths i.e. 0-15 cm and 15-30 cm with increase in cultivation frequency to 2 times cultivator (Farmer Practice). The minimum soil moisture was accompanied with 3 times cultivator practice which might be due to minimum soil porosity and infiltration rate at both the depths associated with this treatment i.e. 3 times cultivator. The pattern of results associated with the treatments such as 2 times cultivator followed by rotavator and cultivator accompanied with rotavator might be due to practice of rotavator which could have sealed the surface of soil, reduced soil porosity and infiltration rate owing to clayey soil texture. These observations are in accordance with the findings of Adugna, 2019 who stated that soil tillage can greatly affect the sustainable use of soil resources through its influence on soil properties.

The pattern of results obtained signifies the importance of variation in tillage frequency regarding soil moisture conservation at 156 DAS. As the soil in the trial's area was clayey reflecting the increased soil porosity at both the depths i.e. 0-15 cm and 15-30 cm with increase in cultivation frequency to 2 times cultivator (Farmer Practice). The minimum soil moisture was accompanied with 3 times cultivator which might be due to minimum soil porosity and infiltration rate at both the depths associated with this treatment i.e. 3 times cultivator. The pattern of results associated with the treatments such as 2 times cultivator followed by rotavator and cultivator accompanied with rotavator might be due to practice of rotavator which could have caused soil surface to be sealed, bringing reduction in soil porosity and infiltration rate as the soil under trial's area was clayey. Deeper tillage had profound effects on soil structure as well as its infiltration capacity and aeration (Riley et al., 2008).

The obtained results highlight the importance of variation in tillage frequency regarding plant growth and development reflected in the form of plant height. As the soil in the test field was clayey depicting the increased soil porosity with increase in cultivation frequency to 3 times cultivator from the farmers practice i.e. 2 times cultivator. Moreover, better growth resources capturing through photosynthesis and via soil solution led to higher plant height in 3 times cultivator run fields of arugula plants. The results are in line with the findings of Ramadhan, 2021 that deep tillage system greatly enhance the plant height of maize plants. Plant height is the reflection of better soil tilth and amount of optimum moisture available to the developing crop that could be used as a measure of vegetative growth (Iqbal et al., 2014).

The trend in results obtained indicates the importance of variation in tillage frequency regarding plant growth and development reflected in the form of siliquae per plant. Significantly, maximum number of siliquae per plant were obtained from farmer practice. It might be due to its adaptability to the particular trial area, edaphic factors i.e. soil porosity, water holding capacity and infiltration rate are particularly acclimatized to this treatment over decade's long practice. Moreover, the presence of more soil moisture during the entire growing season and better nutrient uptake through the soil solution might be the reasons for maximum siliquae per plant from the treatment such as 2 times cultivator (Farmer Practice). Significantly, minimum siliquae per plant were observed from the treatment such as 3 times cultivator. This might be due to minimum availability of resources in terms of soil moisture and nutrient uptake which results in poor metabolic processes of arugula plants. These observations are in contrast with the findings that various tillage practices have no effect on the siliquae per plant of sunflower (Tiritan et al., 2016). This might be due to heterogeneity in the selection of crop i.e. sunflower, soil type, different tillage techniques, sowing method and climatic conditions of the particular experimental area.

The pattern of results obtained indicates the importance of variation in tillage frequency regarding plant growth and development reflected in the form of seeds per siliquae. Significantly, maximum siliquae per plant were obtained from farmer practice. It might be due to its adaptability to the particular trial area, edaphic factors i.e. soil porosity, water holding capacity and infiltration rate are particularly acclimatized to this treatment. Moreover, the presence of more soil moisture (Figure 3 and 4) during the entire growing season and maximum nutrient uptake through the soil solution might be the reasons for maximum number of seeds per siliquae from the treatment such as 2 times cultivator (Farmer Practice). Significantly, minimum number of seeds per siliquae were observed from the treatment such as 3 times cultivator. This might be due to reduced availability of resources in terms of soil moisture and nutrient uptake which results in poor metabolic processes of arugula plants. These findings are in accordance with the results that a greater number of seeds per siliquae were observed from the plots where deep tillage system was practiced i.e. cultivator (Memon et al., 2013). Generally, deep tillage causes an increase in soil aeration which is helpful for crop growth.

The trend of results obtained highlight the importance of variation in tillage frequency regarding plant growth and development reflected in the form of biological yield. As the soil in the test field was clayey thus reflecting the increased soil porosity with an increase in cultivation frequency to 3 times cultivator use from the farmers practice i.e. 2 times cultivator use. Moreover, the possible reasons for highest biological yield from the treatment such as 3 times cultivator were improved availability of resources in terms of soil moisture, nutrient uptake and better sunlight capturing through photosynthesis. Plants would have received sunlight efficiently translating its effect in improved biological yield in 3 times cultivator use as compared to the other treatments. Significantly minimum biological yield was noticed from the plots where 2 times cultivator (Farmer Practice) was run. It might be due to intra-specific competition of arugula plants under study for sunlight, water and minerals. These findings are in accordance with the outcomes that several tillage treatments can significantly enhance biological yield of sunflower (Barros et al., 2004).

The trend in results obtained indicates the importance of variation in tillage frequency regarding plant growth and development reflected in the form of seed yield. Significantly, maximum seed yield was obtained from farmer practice tested plots. It might be due to its adaptability to the particular trial area, edaphic factors i.e. soil porosity, water holding capacity and infiltration rate are particularly acclimatized to this treatment. Moreover, the presence of more soil moisture during the entire growing season and maximum nutrient uptake through the soil solution might be the reasons for maximum seed yield from the treatment 2 times cultivator use (Farmer Practice). Significantly, minimum seed yield was observed from the treatment i.e. 3 times cultivator. This might be due to minimum availability of resources in terms of soil moisture and nutrient uptake which results in poor metabolic processes of arugula plants. The results are in agreement with the findings that deep tillage system had considerable effect on seed yield of sesame crop (Ali et al., 2014). Yol et al., 2010 also reported that maximum seed yield in sesame was recorded where deep tillage operations were practiced.

The trend in results obtained indicates the importance of variation in tillage frequency regarding plant growth and development reflected in the form of harvest index. Significantly, maximum harvest index was obtained from farmer practice, it might be due to its adaptability to the particular trial area, edaphic factors i.e. soil porosity, water holding capacity and infiltration rate are particularly acclimatized to this treatment. Moreover, the presence of maximum soil moisture during the entire growing season and maximum nutrient uptake through the soil solution might be the reasons for maximum harvest index from the treatment such as 2 times cultivator (Farmer Practice). Significantly, minimum harvest index was observed from the treatment such as 3 times cultivator, this might be due to minimum availability of resources in terms of soil moisture and nutrient uptake which results in poor metabolic processes and seed formation of arugula plants. The findings are in line with the results that maximum harvest index associated with the deep tillage practices as compared to shallow tillage operations (Yol et al., 2010).

Economic Analysis

Net profit and the benefit cost ratio (BCR) were calculated as part of the economic analysis according to CIMMYT (1988). Comparative results and the benefits of various treatments were computed by economic analysis. Economic analysis is essential for any recommendation. Variable cost, total fixed cost, net benefit, and additional returns from each treatment were computed to check the benefit cost ratio of each treatment. We computed the cost of production for arugula based on current market pricing for inputs, labor, and goods during the crop's growing season. To access the economic feasibility of various treatments, economic returns (Rs. ha^{-1}) were estimated. Results of field experiment showed significant effect of tillage practices on soil moisture conservation as well as yield attributes respectively. In field experiment, the maximum seed yield and soil moisture conservation were associated with the farmer practice i.e. 2 times cultivator. The field trials shown minimum increment in yield attributes and soil moisture conservation from 3 times cultivator. Likewise, arugula planted fields where 2 times cultivator was practiced at the time of land preparation exhibited better soil moisture availability in rhizosphere and seed yield. However, among new tillage treatments practiced 2 times cultivator followed by rotavator performed superior than 3 times cultivator and cultivator followed by rotavator. It was also evident from the experiment that through proper standardization and its acclimatization under spate irrigated conditions will result in prospect and hope for improving productivity of arugula.

Table 5. Total fixed cost (on hectare basis) for the production of arugula in PKR.

Sr.	Input operations	Unit	Frequency/Quantity	Price (Rs/ha)	Expenditure (Rs /ha)
1	Land preparation	Hectare	8- Times Cultivator + Rotavator	3000+4000=7000	7000*2.47=17290
2	Seed	Kg ha^{-1}	5 kg	324	324*2.47=800
3	Sowing	Hectare	Seed drill	2000	2000*2.47=4940
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	Bund maintenance cost	Hectare	Tractor + Blade + Labour	3000 + 1200 + 1400=5600	5600*2.47=13832
8	Water diversion cost	Hectare	Tractor + Blade	2250 + 1200=3450	3450*2.47=8500
9	Land rent	Month	6	7500	7500*2.47=18525
Total					82,595

Table 6. Benefit cost ratio (on hectare basis) for the production of arugula in PKR.

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
2 Times Cultivator	570	114000	1729	86450	200450	82595	1350	83945	116505	1.41
3 Times Cultivator	460	92000	1856	92800	184800	82595	1890	84485	100315	1.21
2 Times Cultivator + Rotavator	515	103000	1765	88250	191250	82595	2160	84755	106495	1.28
Cultivator + Rotavator	482	96400	1803	90150	186550	82595	1620	84215	102335	1.23

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
T.C: Total Cost
Note: 1 USD: 163 PKR

CONCLUSION

Under the prevailing agro normals, farmers of hill torrent-based production system may use 2 times cultivator for land preparation for better arugula productivity. Two times cultivator followed by rotavator may be further tested in clayey soil for improved moisture conservation and arugula productivity in hill torrent-based crop production system.

ACKNOWLEDGEMENTS

Authors are thankful to the Department of Agriculture Extension Dera Ghazi Khan Punjab, Pakistan for provision of weather data and Fatima Fertilizers Company Ltd. for assisting in soil analysis.

REFERENCES

Ahmad, M., M. Arshad, M. J. M. Cheema and R. Ahmad. 2016. Comparison of available water resources for irrigation mithawan hill torrent command area of dera ghazi khan, Pakistan. Pakistan Journal of Agriculture Sciences, 53: 233-240.

Ali, S., A. Jan, Inamullah, S. Ahmad, M. Ullah and Imran. 2014. Effect of tillage systems, irrigation intervals and phosphorus levels on oil content, yield and yield components of sesame. Journal of Environment and Earth Sciences, 4: 7-12.

Amin, A.M., K. Mubeen, M. Ahmad, M. Aziz and M. Arif. 2019. Strip intercropping system of chickpea, lentil and arugula as a promising option in spate irrigated area of Punjab, Pakistan. Asian Journal of Agriculture and Biology, 7: 146-155.

Adugna, O. 2019. Effects of tillage practices and cropping system on soil physical properties and in-situ water conservation in clay loam of Assosa, Ethiopia. International Journal of Agricultural Research, 7: 794–802.

FAO, 2022a. Economics of spate irrigation. Accessed on 10 Dec 2021. Online available at http://www.fao.org/home/en.

PARC. 2022b. Oil Seed Program NARC, Islamabad. Accessed on 17 Feb 2022. Online Available at http://www.parc.gov.pk/index.php/en/csi/137-narc/crop-sciences-institue/713-oil-seed-program.

Barron, J., J. Rockstrom, F. Gichuki and N. Hatibu. 2003. Dry spell analysis and maize yields for two semi-arid locations in east Africa. Agricu. Agricultural and forest meteorology, 117: 23-37.

Blanco, C., H., B.J. Wienhold, V.L. Jin, M.R. Schmer and L.C. Kibet. 2017. Long-term tillage impact on soil hydraulic properties, Soil and Tillage Research, 170: 38- 42.

Barros, J.F.C., M. de Carvalho and G. Basch. 2004. Response of sunflower (Helianthus annus L.) to sowing date and plant density under Mediterranean conditions. European Journal of. Agronomy, 21: 347-356.

CIMMYT.1988. Economics program, international maize and wheat improvement center. From agronomic data to farmer recommendations: An economics training manual (No. 27).

Dhar, S., S.K. Das, S. Kumar and J.B. Singh. 2008. Effect of tillage and soil moisture conservation practices on crop yields of chickpea. The Indian Journal of Agricultural Sciences, 78: 42-53.

Ekin, A., M. Tuncturk and I. Yilmaz. 2005. Evaluation of seed, oil yields and yield properties of different sunflower (Helianthus annuus L.) hybrid varieties in Van, Turkey. Pakistan Journal of Sciences, 8: 683-686.

Grabowski, P. P. Haggblade, S. Kabwe and G. Tembo. 2014. Minimum tillage adoption among commercial smallholder cotton farmers in Zambia, 2002 to 2011. Agriculture System, 131: 34-44.

Gul, B., H. Ali, M.Y. Adnan, M.Z. Ahmed, I. Aziz, S. Gulzar, R. Ansari and M.A. Khan. 2014. NPK mediated improvement in biomass production, photosynthesis and Na+ regulation in Panicum antidotale under saline conditions. Pakistan Journal of Botany, 46: 1975-1979.

Hanna, M. and M.M. Al-Kaisi. 2009. Resources conservation practices; managing and understanding soil compaction, Iowa University Extension article PM 1094.

Iqbal, M., A.G. Khan, R. Mukhtar and S. Hussain. 2014. Tillage and N fertilization effect on wheat yield, organic carbon and total N.J. Sustainable Watershed Science Management, 2: 108-117.

Jardina, L.L., C.A.M. Cordeiro, M.C.C. Silva, A.G. Sanches and P.V. A. Júnior. 2017. Productive performance and quality of arugula cultivars in semi-hydroponic system. Revista de Agricultura Neotropical, 4: 78-82.

Javed, M. Y., M. Nadeem and F. Javed. 2007. Pakistan: additional works for the preparation of hill torrent management plan. Technical Assistance Consultant's Report, Irrigation and Power Deptt. Punjab, Islamabad, Pakistan.

Khursheed, S. C., Simmons, A. Sartaj, T. Ali, R. Sk and N. Gr. 2019. Conservation tillage: impacts on soil physical conditions – an overview. Statistical procedures for agricultural research, 9: 342–346.

Li, J., Y. K. Wang, Z. Guo, J. B. Li, C. Tian, D. W. Hua and Y. Xu 2020. Effects of conservation tillage on soil physicochemical properties and crop yield in an arid Loess Plateau, China. Scientific Reports, 10: 1-15.

Mubeen, K. 2022. Hill Torrent Water: A potential water source for Pakistan. Accessed on 10 May, 2022. Online Available at https://mnsuam.edu.pk/index.php/blogs.

Memon, S.Q., M.S. Mirjat, A.Q. Mughal and N. Amjad. 2013. Effect of conventional and non-conventional tillage practices on maize and oilseed production. Pakistan Journal of Agriculture Engineering Veterinary Sciences, 29: 155-163.

Oliveira, F.A, M.L Souza, M.L. Neta, R.T. Silva, A.A.T. Souza, M.K.T. Oliveira and J.F. Medeiros. 2013. Performance of rocket cultivars under different nutritive solutions with salinity different. Rev Agro@mbiente On-line, 7:170-178.

Riley, H., R. Pommereche, R. Eltun, S. Hansen and A. Korsaeth. 2008. Soil structure, organic matter and earthworm activity in a comparison of cropping systems with contrasting tillage, rotations, fertilizer levels and manure use. Agriculture Ecosystem and Environment, 124: 275-284.

Ramadhan, M. N. 2021. Yield and yield components of maize and soil physical properties as affected by tillage practices and organic mulching. Saudi Journal of Biology Science, 28: 7152-7159.

Strudley, M.W. T.R. Green and J.C. Ascough. 2008. Tillage effects on soil hydraulic properties in space and time: State of the science. Soil Tillage Research, 99: 4-48.

Steel, R.G.D, J.H. Torrie and D.A. Dickey. 1997. Principles and procedures of statistics: A biometrical approach. 3rd Ed. McGraw Hill Book Co. Inc., New York, USA. p352-358.

Tiritan, C.S., L.T. Bill, C.A. Crusiol, A.C.C. Filho, D.M. Fernandes and A.S. Nascente. 2016. Tillage system and lime application in a tropical region. Soil chemical fertility and corn yield in succession to degraded pastures. Soil Tillage Research, 155: 437-447.

Yol, E., E. Karaman, S. Furat and B. Uzun. 2010. Assessment of selection criteria in sesame by using correlation coefficients, path and factor analyses. Australian Journal of Crop Sciences, 4: 598-602.