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Research Article

Evaluating potential of dry afforestation techniques on barren land in Attock

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ABSTRACT

Deforestation poses a serious environmental threat turning huge vegetative areas into barren lands in Pakistan and may also cause the extinction of native plant species and wildlife. Pothowar plateau being located in the semiarid zone of Pakistan is severely affected by erosion because of less forest cover and less rainfall resulting in large areas shifting to barren lands. Deforestation, unpredictability, and short durational rainfall are the key causative agents. Dry afforestation is a well-known technique for land reclamation in arid and semi-arid areas. Dry afforestation is an efficient way of utilizing rainwater for tree growth and increasing vegetative cover. This research was conducted in Attock (located in the Pothowar plateau). The research duration was one year (February 2022-2023). The main objective of this research was the evaluation and comparison of dry afforestation techniques in terms of indigenous vegetation growth so that rainwater can be utilized to the maximum extent. Two different dry afforestation techniques including troughs and bunds were tested to reclaim the barren area. Three indigenous species including *Acacia nilotica*, *Acacia modesta*, and *Dodonaea viscosa* were selected for study purposes on dry afforestation techniques. The performance potential of both techniques was evaluated based on different plant growth parameters. Results from plant growth data concluded that, in terms of plant height *Dodonaea viscosa* and *Acacia nilotica* performed better on troughs while *Acacia modesta* performed better on bunds with significant variation in *Acacia modesta* and *Acacia nilotica* tree species. In terms of the number of leaves, there was no significant variation found after analysis. However, *Dodonaea viscosa* and *Acacia nilotica* performed better on bunds while *Acacia modesta* performed better on troughs. In terms of the number of branches *Dodonaea viscosa* and *Acacia nilotica* performed better on bunds while *Acacia modesta* showed better growth on troughs.

Keywords: Barren lands, bunds, dry afforestation, troughs, water conservation.

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INTRODUCTION

Forests are essential for human survival and the economy around the world. Forest land is defined as land with at least 0.5 hectares of land area having a potential canopy cover of 10% and at least 5m of potential tree height (FAO 2000; Korhonen et al., 2006). The global forest area decreased by 3%, from 4128 million hectares (Mha) in 1990 to 3999 Mha in 2015. Between 2010 and 2015, the annual rate of net forest loss is predicted to have decreased from 7.3 Mha in the 1990s to 3.3 Mha. Between 1990 and 2015, the natural forest area decreased from 3961 to 3721 Mha (Keenan et al., 2015). If we consider Pakistan, the United Nations (UN) Food and Agriculture Organization (FAO) produced a report on the state of the world in 2009 which indicates that Pakistan barely has 2.5% of its land covered with forest, the annual rate of deforestation is 2.1%; no Asian country has a higher rate of forest degradation compared to this.

While according to the government of Punjab Forest cover of Pakistan is only 4.5 million hectares, or 5.1% of the total area, far less than the international minimum which is 25% (GOP, 2015). Scrub forest is the least productive forest type but has a key role in soil and water conservation. Scrub forests are majorly present in the Pothowar Pleatue. Considering climatic conditions of the Pothowar range in Pakistan, rainfall is usually scarce so to utilize precipitation water dry afforestation techniques are used by the provincial forest department to grow forest cover area because these techniques utilize maximum rainwater and give maximum output in these types of areas (Sheikh, 1981). Dryland afforestation techniques also known as water harvesting or water conservation techniques are defined as the practices or equipment and procedures for collecting, storing, and using precipitation water for vegetation growth on drylands or barren lands (Critchley et al., 2013; Moges, 2004; Audrey, 2005). Many variables, including natural causes such as drought and desertification, make tree regeneration and afforestation on barren lands a tackling process. Some human-related factors include Irrational agriculture, overgrazing, over-exploitation, and fires (Evans, 2001).

Dry afforestation techniques are of paramount global significance due to their diverse and far-reaching benefits. They aid in restoring degraded arid landscapes by promoting biodiversity, stabilizing soil, preventing erosion and enhancing water retention. This contributes to ecosystem restoration and the provision of vital services. Additionally, these techniques play a pivotal role in mitigating climate change by sequestering carbon dioxide through tree and plant growth, improving water resource management by increasing groundwater recharge, reducing runoff, and serving as natural water filters (Saeed et al., 2021). Dry afforestation techniques hold socio-economic importance by creating jobs, supporting sustainable livelihoods, and yielding non-timber forest products. It also serves as a strategy for disaster risk reduction by minimizing the impact of natural disasters and contributes to biodiversity conservation by establishing habitats and ecological corridors. The practice fosters research, education, and international collaboration while enhancing resilience to climate variability. In essence, dry afforestation serves as a holistic approach to address various challenges in arid and degraded environments, spanning ecosystem restoration, climate change mitigation, water management, socio-economic development, disaster resilience, biodiversity conservation, and global cooperation (Shahbaz et al., 2013).

Dry afforestation techniques have been successfully implemented in other regions with annual rainfall of 80mm. Some of these techniques are being investigated and found efficient in Pakistan's dry zone when annual average rainfall exceeds 200mm. The needs of local communities can be met effectively if precipitation in a dry location is captured from a vast area and stored appropriately. Water conservation has two types in-situ and ex-situ. In-situ water harvesting involves capturing of runoff rainwater in the field or at the crop production site. Pitting and semi-circle bunds are two examples of it. Ex-situ water harvesting involves capturing runoff rainwater from a broader area and storing that water in a location separate from the collection spot. After that rainwater is transferred to the growing region through ducts. Terraces and dead-level terraces are examples of approaches employed (Gowing et al.,1999).

MATERIALS AND METHODS

Experimental Site Attock previously known as Campbellpur is a rather large district of Punjab province. Attock is a section of the Pothohar plateau, which is situated on the watershed of Attock River and surrounded by hilly terrain. This area lies between 1000 and 1145 feet above sea level in elevation. Attock is situated in 33.77° north latitudinal line and 72.36° east longitudinal line.

Tree Species Selection

The following three native tree species were selected for the collection of plant growth data:

Acacia modesta (Phulai) *Acacia nilotica* (Kikar) *Dodonaea viscosa* (Sanatha)

Site for Plant Growth Data Collection

The site which was selected for data collection of plant growth was located in Attock city having coordinates Latitude:33.85374 & Longitude:72.33859. Dry afforestation techniques were implanted/established here by the Punjab Forest Department under the Ghazi Brotha Hydropower Project (GBHP) between 01 February-15 March 2022 on an area of three hundred acres. Two dry afforestation techniques i.e., Bund formation and Trough formation are being used in Attock.

Data Collection

As the plantation was done during February-March 2022, data collection was done during March i.e., 10-20 March 2023 exactly after one year. The research site was distributed using one percent sampling intensity (1%).

Plot Size

Ten-meter radios (10m) circular plots were selected randomly on twelve different locations using a random sampling technique. Each plot included one trough and one bund upon which data of three different parameters were collected.

Parameters

Three different parameters were studied in this research which included plant height, number of branches, and number of leaves.

Statistical Analysis

Statistical analysis of research data was done using descriptive and inferential statistics using Microsoft Excel and Statistical Package for Social Sciences.

RESULTS AND DISCUSSION

Effect of Bunds and Trough Techniques on Plant Height (cm) of Sanatha

The graphical representation of the effect of bund and trough techniques on the plant height of plant species is described in Figure (1). Sanatha performed better in troughs techniques. The graph shows that most of the plots showed a significant increase in plant height under the Trough technique. Under bunds, the maximum mean value of plant height was recorded in Plot 12 (35). In comparison, the minimum mean value of plant height was recorded in Plot 4 (16). Under trough, the maximum mean value of plant height was recorded in Plot 9 (35.5). At the same time, the minimum mean value of plant height was recorded in Plot 2 (18.9).

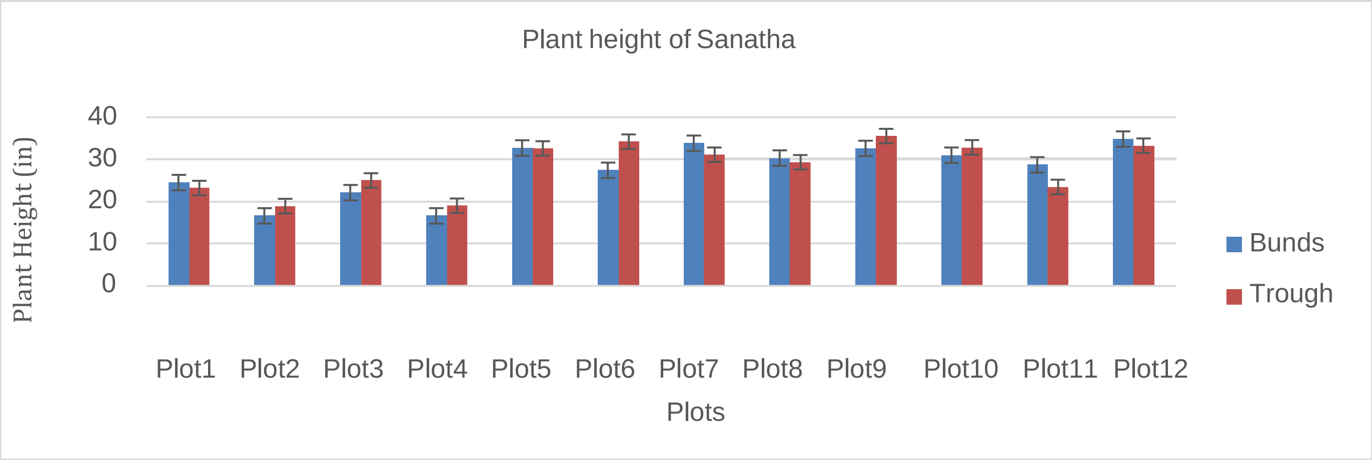

Figure 1. Comparison of bunds and trough techniques on plant height (cm) of Sanatha.

Effect of Bunds and Trough Techniques on Plant Height (Cm) Of Phulai

The graph in Figure (2) shows that most of the plots showed a significant increase in plant height under the bund technique. Under bunds, the maximum mean value of plant height was recorded in Plot 1 (30). In comparison, the minimum mean value of plant height was recorded in Plot 11 (22.1). Under trough, the maximum mean value of plant height was recorded in Plot 3 (32.3). At the same time, the minimum mean value of plant height was recorded in Plot 11 (20.1).

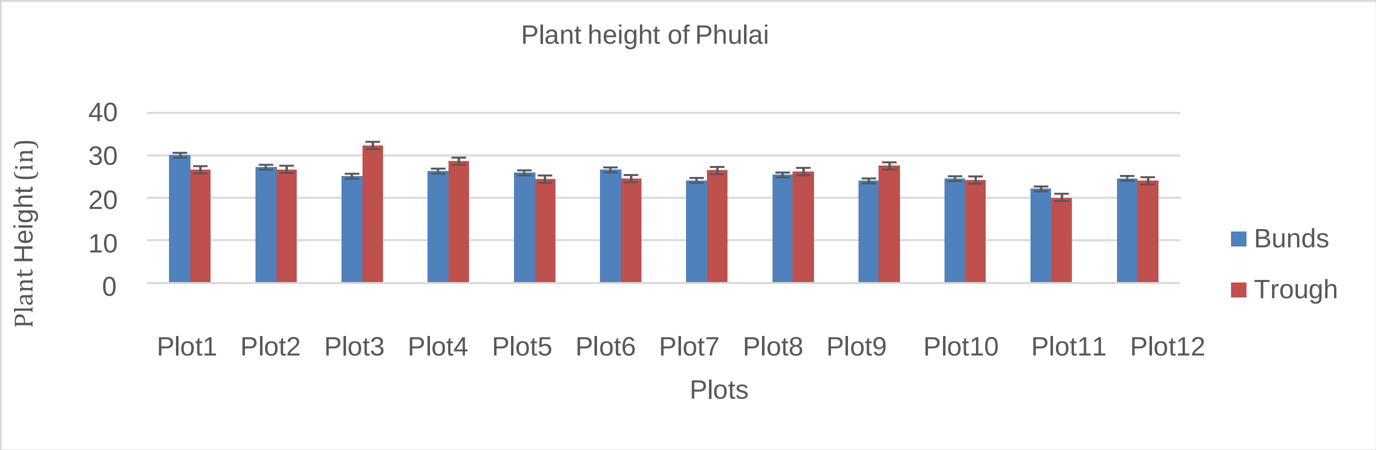

Figure 2. Comparison of bunds and trough techniques on plant height (cm) of Phulai.

Effect of Bunds and Trough Techniques on Plant Height (Cm) of Kikar

The graphical representation of the effect of bund and trough techniques on the plant height of Kikar has been presented in Figure (3). The content of the figure reveals that both treatments differ significantly from each other. The data reveals that maximum plant height was found in the Trough technique. The graph shows that most of the plots showed a significant increase in plant height under the Trough technique. Under bunds, the maximum mean value of plant height was recorded in Plot 8 (49.2). In comparison, the minimum mean value of plant height was recorded in Plot 4 (20.6). Significant variations were found in this parameter after performing an analysis of variance. Under trough, the maximum mean value of plant height was recorded in Plot 5 (53.6). At the same time, the minimum mean value of plant height was recorded in Plot 2 (17.6).

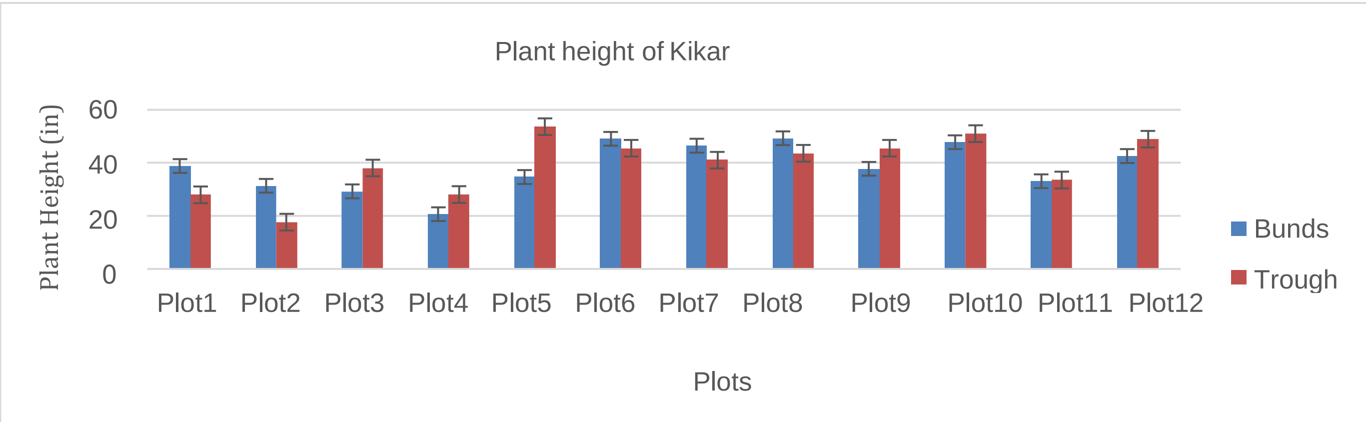

Figure 3. Comparison of bunds and trough techniques on plant height (cm) of Kikar.

Effect of Bunds and Trough Techniques on No. Of Leaves for Sanatha

The graphical representation of the effect of bund and trough techniques on the number of leaves of Sanatha has been presented in Figure (4). The content of the figure reveals that both treatments do not differ significantly from each other. Under bunds, the maximum mean value of the number of leaves was recorded in Plot 2 (2082). In comparison, the minimum mean value of the number of leaves was recorded in Plot 6 (702). Under trough, the maximum mean value of the number of leaves was recorded in Plot 4 (1948). At the same time, the minimum mean value of the number of leaves was recorded in Plot 11 (363).

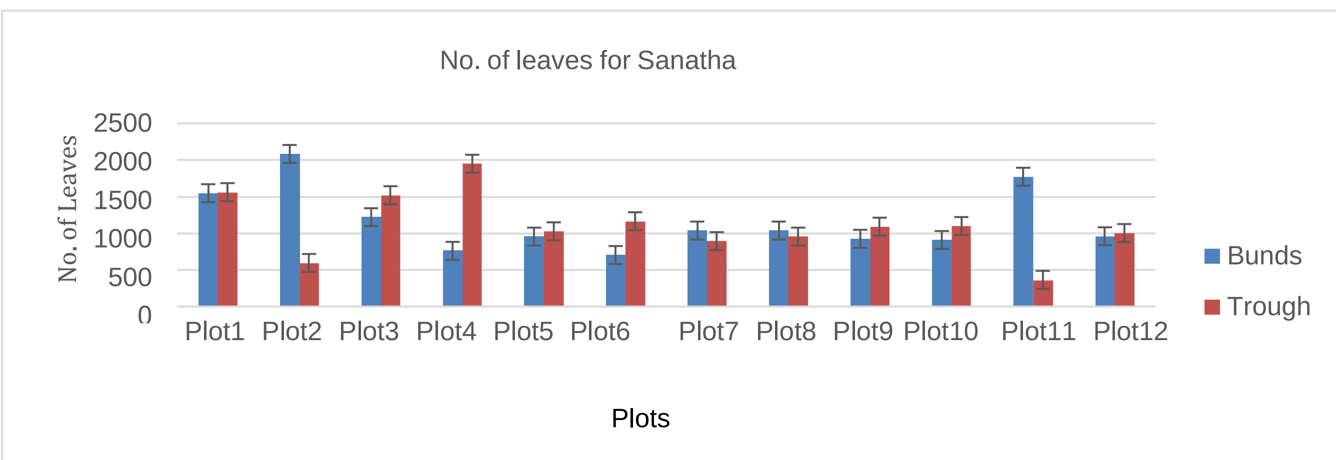

Figure 4. Comparison of bunds and trough techniques on No. of leaves for Sanatha**.**

Effect of Bunds and Trough Techniques on No. of Leaves for Phulai

The graphical representation of the effect of bund and trough techniques on the number of leaves of Phulai has been presented in Figure (5). The content of the figure reveals that both treatments do not differ significantly from each other. The data reveals that a maximum number of leaves was found in the Trough technique. The graph shows that most of the plots showed a significant increase in number of leaves under the Trough technique. Under bunds, the maximum mean value of the number of leaves was recorded in Plot 6 (2182). In comparison, the minimum mean value of the number of leaves was recorded in Plot 11 (835). Under trough, the maximum mean value of the number of leaves was recorded in Plot 4 (2426). At the same time, the minimum mean value of the number of leaves was recorded in Plot 10 (515).

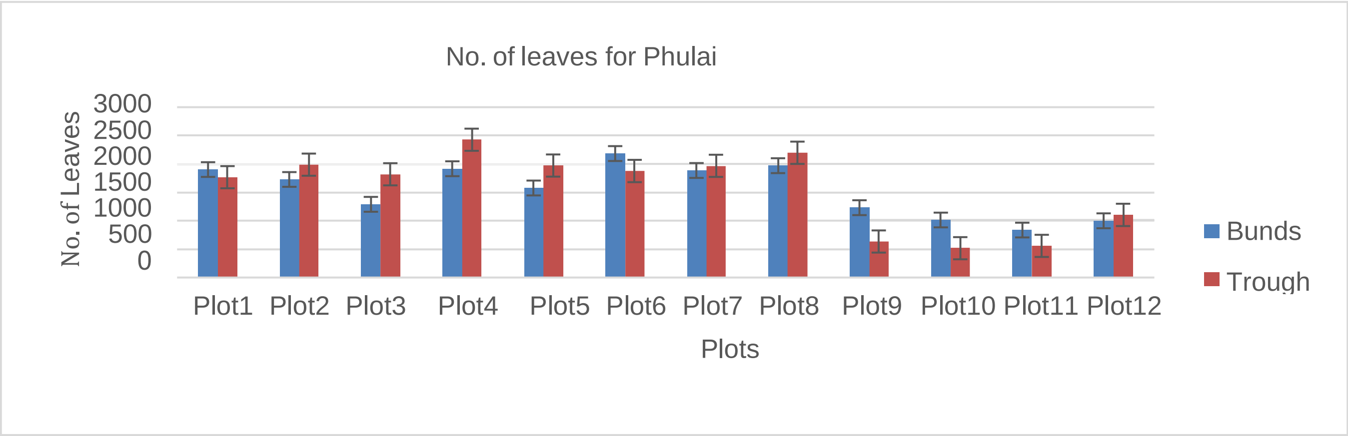

Figure 5. Comparison of bunds and trough techniques on No. of leaves for Phulai.

Effect of Bunds and Trough Techniques on No. of Leaves for Kikar

Figure (6) shows that most of the plots showed a significant increase in number of leaves under the Bund technique. Under bunds, the maximum mean value of the number of leaves was recorded in Plot 11 (961). In comparison, the minimum mean value of the number of leaves was recorded in Plot 12 (107). Under trough, the maximum mean value of the number of leaves was recorded in Plot 5 (608). At the same time, the minimum mean value of the number of leaves was recorded in Plot 12 (115).

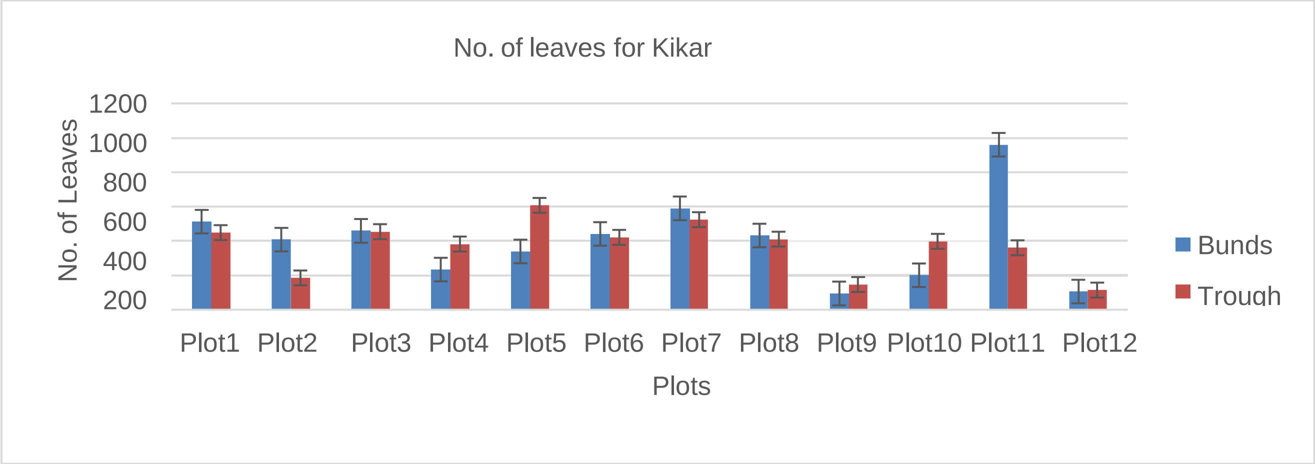

Figure 6. Comparison of bunds and trough techniques on No. of Leaves for Kikar.

Effect of Bunds and Trough Techniques on No. of Branches for Sanatha

The graphical representation of the effect of bund and trough techniques on the number of branches of Sanatha has been presented in Figure (7). The data reveals that a maximum number of branches was found in the Bund technique. The graph shows that most of the plots showed a notable surge in the number of branches under the Trough technique. Under bunds, the maximum mean value of the number of branches was recorded in Plot 1 (46). In comparison, the minimum mean value of the number of branches was recorded in Plot 4 (19.6). Under trough, the maximum mean value of the number of branches was recorded in Plot 3 (44.4). At the same time, the minimum mean value of the number of branches was recorded in Plot 7 (20.4).

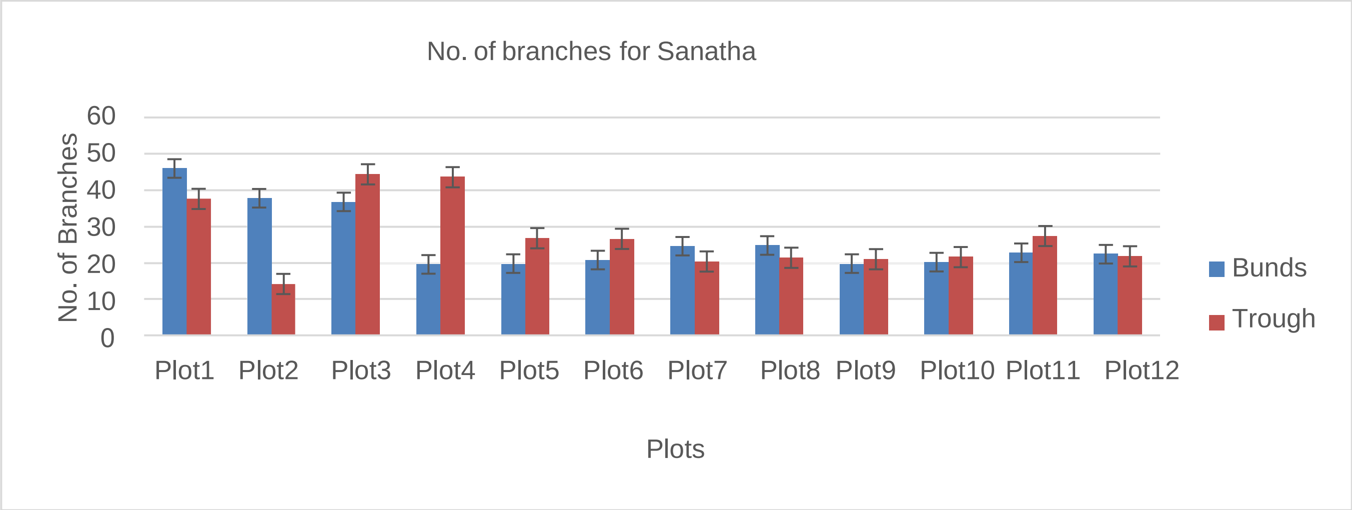

Figure 7. Comparison of bunds and trough techniques on No. of branches for Sanatha.

Effect of Bunds and Trough Techniques on No. of Branches for Phulai

The data (Figure 8) reveals that maximum plant height was found in the Trough technique. The graph shows that most of the plots showed a significant increase in the number of branches under the Trough technique. Under bunds, the maximum mean value of the number of branches was recorded in Plot 6 (25), followed by Plot 8 (23) and Plot 4 (22). In comparison, the minimum mean value of the number of branches was recorded in Plot 3 (16). Under trough, the maximum mean value of the number of branches was recorded in Plot 4 (28). At the same time, the minimum mean value of the number of branches was recorded in Plot 10 (13.8).

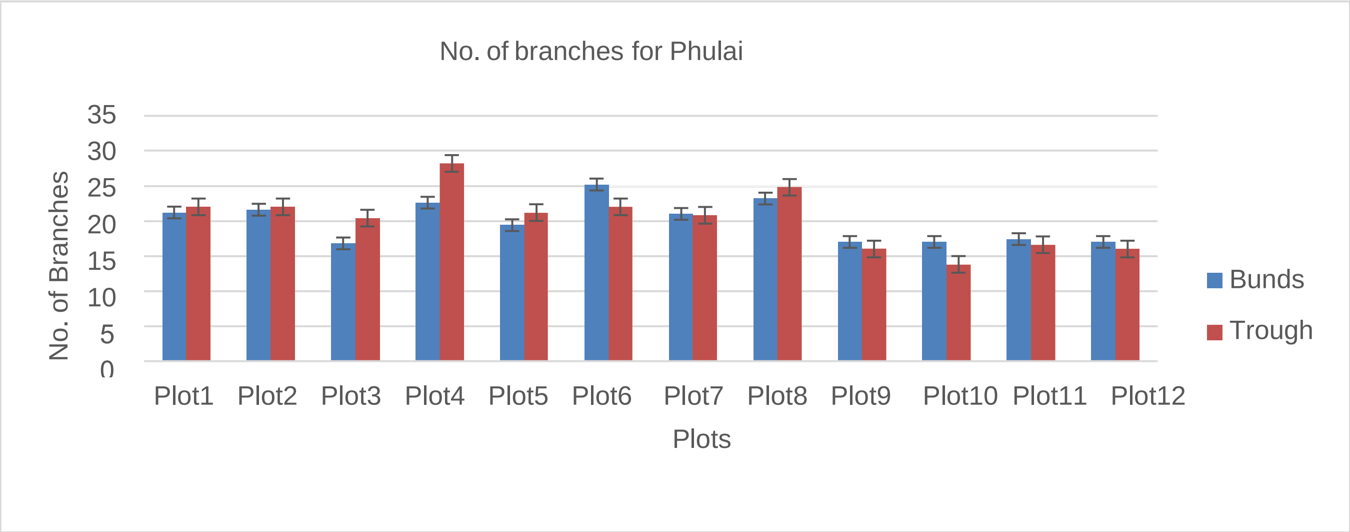

Figure 8**.** Comparison of bunds and trough techniques on No. of branches for Phula**i.**

Effect of Bunds and Trough Techniques on No. of Branches for Kikar

The data in Figure (9) reveals that maximum plant height was found in the Trough technique. The graph shows that most of the plots showed a significant increase in the number of branches under the Bund technique. Under bunds, the maximum mean value of the number of branches was recorded in Plot 11 (25), followed by Plot 10 (24) and Plot 7 (23). In comparison, the minimum mean value of the number of branches was recorded in Plot 5 (11), followed by Plot 4 (12) and Plot 2 (17). No significant variations were found in this parameter after performing an analysis of variance. Under trough, the maximum mean value of the number of branches was recorded in Plot 10 (28) and followed by Plot 9 (27) and Plot 12 (26). At the same time, the minimum mean value of the number of branches was recorded in Plot 2 (11). Bunds and troughs have different effects on plant height. Bunds have been found to have a positive effect on vegetation cover and plant production (Schwarz, 2012). They can enhance soil properties which include organic carbon, nitrogen, phosphorus, and potassium, leading to improved plant growth (Kanannavar et al., 2020). On the other hand, troughs are designed to supply nutrient-enriched water to plants at inaccessible heights (Fried et al., 2018). They ensure a continuous water supply to the plants, which is essential for their growth and development (Khosravi et al., 2016).

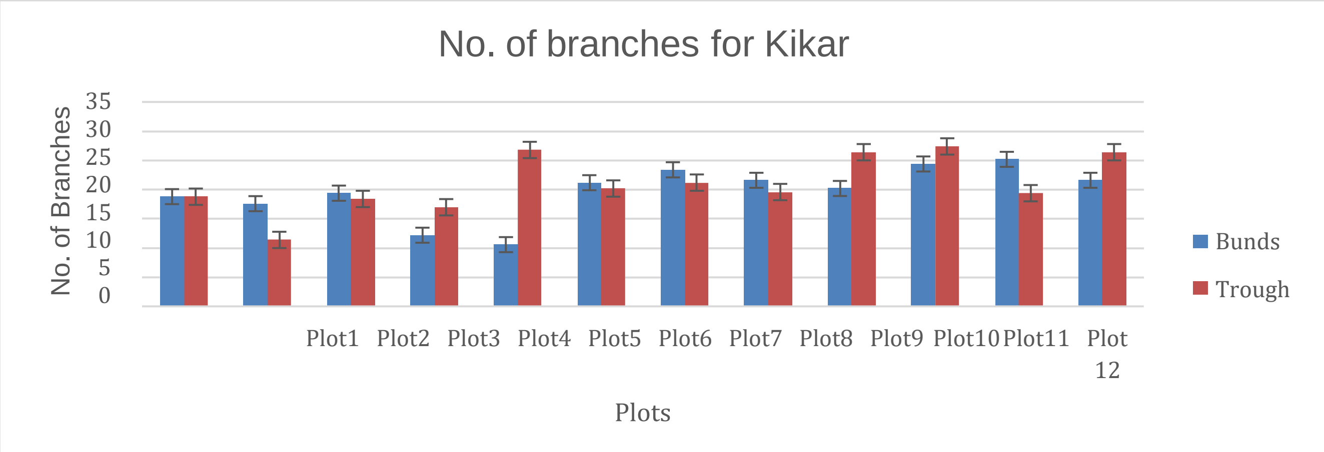

Figure 9. Comparison of bunds and trough techniques on No. of branches for Kikar.

Bunds and troughs have different effects on the number of leaves for Sanatha. The study by Tadesse et al. (2016) found that soil bunds integrated with tree fodder species had a positive effect on soil characteristics and carbon storage. On the other hand, the research by Horf and Robins (2000) focused on the impact of soil bunds on the reduction of runoff, soil erosion, nutrient loss, and improvement of crop yield. They found that soil bunds reduced runoff and soil losses but did not enhance crop production. The use of bunds and trough techniques can have a positive effect on the number of leaves for Phulai plants. These techniques, such as parapet bunds and stone bunds, help to manage the hydrology of the ecosystem and support the growth of indigenous planta Integrating tree fodder species with soil bunds had a positive effect on the characteristics of soil and the amount of carbon stored in semi-arid regions located in the northern part of Ethiopia. By retaining water on the surface behind the bunds, the growing layer of the bog can be re-saturated, preventing subsidence and promoting the reconsolidation of plants (Wolka et al., 2011). Table (1) compares plant characteristics between two dry afforestation techniques, bunds and troughs. For plant height, troughs generally have higher values, with a mean of 28.18 compared to 27.59 in bunds. The number of branches and leaves also varies, showing higher variability in bunds. For instance, bunds have a wider range of leaves (330 to 2992) compared to troughs (130 to 2800), with bunds having a higher mean (1158.45) than troughs (1101.10). Standard deviation and standard error values indicate the degree of variability and precision in the measurements, respectively, with differences observed between the two cultivation techniques. Table (2) dataset compares plant characteristics between bunds and troughs. While plant height is similar in both techniques, bunds exhibit less variability and greater precision in measurements. The number of branches shows comparable means but lower variability in bunds. Regarding the number of leaves, troughs generally have a higher mean and median, indicating more leaves on average, while bunds display greater variability. Overall, these findings suggest differences in variability and central tendencies between bunds and troughs in terms of plant height, number of branches, and number of leaves. Table (3) compares plant characteristics between bunds and troughs. In terms of plant height, troughs generally exhibit higher values than bunds, with a mean of 39.51 compared to 37.70. The number of branches is also higher in troughs, with a mean of 21.08 compared to 19.68 in bunds. However, bunds have a wider range of branches, as indicated by the higher maximum value (55) compared to troughs (38). Regarding the number of leaves, bunds have a higher mean (398.88) compared to troughs (371.87), suggesting a greater leaf count on average. However, troughs have a higher median and mode, and a lower standard deviation, indicating less variability in leaf count compared to bunds. Overall, the above data highlights differences in plant height, number of branches, and number of leaves between bunds and troughs.

Dry afforestation techniques are used to increase forest cover and combat land degradation in dry areas. The use of bunds and trough techniques has been found to affect plant height positively. O'Kelly (2008) found that using semi-circular bunds and troughs in arid and semi-arid rangelands causes a considerable increase in vegetation cover. Additionally, using stone bunds, in West African Sahel farming systems showed promising outcomes by increasing plant height, and productivity and capturing more rainwater, which could contribute to securing farmers' livelihoods (Mousavi et al., 2019). Soil bunds integrated with tree fodder species have been shown to positively affect plant height in northern Ethiopia's semi-arid areas (Schwarz, 2012). Our study showed that under troughs plant height of *Dodonaea viscosa* and *Acacia nilotica* increases which is in line with the results of Mousavi et al. (2019). Troughs are designed to supply nutrient-enriched water to plants in small areas at inaccessible heights (Stegelmeier et al., 2022), and bunds are implemented to reclaim degraded land and improve soil properties by covering larger areas (Tadesse et al., 2016). Troughs ensure a consistent water supply to plants, which can contribute to their growth and development (Kanannavar et al., 2020). On the other hand, bunds have been found to increase vegetation cover, plant production, and density (Khosravi et al., 2016). Additionally, they enhance soil quality by increasing its organic carbon, nitrogen, potassium, phosphorus, and calcium carbonate levels. These findings suggest that bunds can positively impact several branches and plant height by creating favorable conditions for plant growth, which aligns with our findings. It is essential to understand that the effects of bund techniques may differ based on the type of technique used and the environmental conditions of the study area. Bunds and troughs have different effects on the number of leaves for *Dodonaea viscosa* and *Acacia modesta*. The study by Tadesse et al. (2016) found that soil bunds integrated with tree fodder species had a positive effect on soil characteristics and carbon storage. On the other hand, the research by Horf and Robins (2000) focused on the impact of soil bunds on the reduction of runoff, soil erosion, nutrient loss, and improvement of crop yield. They found that soil bunds reduced runoff and soil losses but did not enhance crop production.

Table1. Statistical analysis of sanatha in bund/trough techniques

Parameters	Techniques	Number of Plants (N)	Mean	Median	Mode	Standard Deviation	Standard Error	Minimum	Maximum
Plant Height	Bunds	60	27.59	28.00	28	9.37	1.21	10	44
	Troughs	60	28.18	28.50	0	9.09	1.17	11	44
No. of Branches	Bunds	60	26.28	22.00	19	13.11	1.69	11	75
	Troughs	60	27.23	23.50	19	13.51	1.74	9	70
No. of Leaves	Bunds	60	1158.45	994.50	0	695.78	89.82	330	2992
	Troughs	60	1101.10	1014.00	0	648.44	83.71	130	2800

Table 2. Statistical analysis of phulai in bund/trough techniques.

Parameters	Techniques	Number of Plants(N)	Mean	Median	Mode	Standard Deviation	Standard Error	Minimum	Maximum
Plant Height	Bunds	60	25.77	25	24	5.02	0.65	12	37
	Troughs	60	25.96	26	0	5.60	0.72	12	36
No. of Branches	Bunds	60	19.95	20	0	4.78	0.62	11	30
	Troughs	60	20.32	20	20	5.50	0.71	9	30
No. of Leaves	Bunds	60	1543.62	1406	1200	613.99	79.27	480	2730
	Troughs	60	1568.73	1704	1820	764.56	98.70	180	2940

The construction of soil bunds led to a reduction in cultivable area and a decrease in crop yield. In the case study presented by O'Kelly (2008), the construction of parapet bunds led to the re-saturation of the growing layer, which can potentially impact the number of leaves produced by *Dodonaea viscosa* and *Acacia modesta*. The study by Siddiqui et al. (2010) found that traditional pruning, which involves crown removal, resulted in a reduction in the diameter growth of *Acacia nilotica* trees.

Table 3. Statistical analysis of kikar in bund/trough techniques.

Parameters	Techniques	Number of Plants(N)	Mean	Median	Mode	Standard Deviation	Standard Error	Minimum	Maximum
Plant Height	Bunds	60	37.70	35.25	0	13.34	1.72	12	68
	Troughs	60	39.51	38.50	43	14.48	1.87	12	72
No. of Branches	Bunds	60	19.68	19.00	19	7.58	0.98	6	55
	Troughs	60	21.08	21.00	0	7.19	0.93	6	38
No. of Leaves	Bunds	60	398.88	367.50	0	314.61	40.62	0	1980
	Troughs	60	371.87	369.00	0	242.43	31.30	0	810

However, the study by Tadesse et al. (2016) focused on the effectiveness of integrating tree fodder species into soil bunds on soil properties and carbon stock and did not specifically mention the effect on the number of leaves. The number of branches is more dominant in *Dodonaea viscosa* when using the bunding technique rather than the troughing technique (Norklit & Vaughan, 1998) which has proven correct from our research in which *Dodonaea viscosa* and *Acacia nilotica* showed a greater number of branches in bunds then in troughs.

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REFERENCES

Audrey, A. P. (2005). City of Tucson Water Harvesting Guidance Manual. The City of Tucson.

Critchley, W., Siegert, K., Chapman, C., & Finket, M. (2013). Water harvesting: A manual for the design and construction of water harvesting schemes for plant production. Scientific Publishers.

Evans, J. 2001. The Forests Handbook in Bhatia. An Overview of Forest Science. Blackwell Publishing.

FAO, F. (2000). On Definitions of Forest and Forest Change, Forest Resources Assessment Programme. Working Paper 33, Rome.

Fried, O., Kühn, I., Schrader, J., Sinh Nguyen, V., & Bergmeier, E. (2018). Plant diversity and composition of rice field bunds in Southeast Asia. *Paddy and Water Environment*, 16, 359-378.

Gowing, J. W., Mahoo, H. F., Mzirai, O. B., & Hatibu, N. (1999). Review of rainwater harvesting techniques and evidence for their use in semi-arid Tanzania. *Tanzania Journal of Agricultural Sciences*, 2(2).

Horf, M. C., & Robins, A. G. (2000). The effect of'small'bunds on the dispersion around large buildings. WIT *Transactions on Ecology and the Environment*, 42.

Kanannavar, P. S., Punitha, B. C., & Shanawad, U. K. (2020). Effect of Field Topographic Conditions on Plant Height of Rabi Sorghum in Vertisols. *International Journal of Current Microbiology and Applied Sciences*, 9:1349-1354.

Keenan, R. J., Reams, G. A., Achard, F., de Freitas, J. V., Grainger, A., & Lindquist, E. (2015). Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. *Forest Ecology and Management*, 352, 9-20.

Khosravi, H., Ebrahimi, M., & Rigi, M. (2016). Semi-circular bunds effect on the restoration of plant vegetation and soil properties in Koteh Rangeland, Sistan and Balochistan Province, Iran. *Journal of Rangeland Science*, 6(4), 355-367.

Korhonen, L., Korhonen, K. T., Rautiainen, M., & Stenberg, P. (2006). Estimation of forest canopy cover: a comparison of field measurement techniques.

Moges, Y. (2004). Water harvesting techniques: Training and construction manual. Consultancy sub-report number 2. *Tropical Forestry*.

Mousavi, H., Masoudi, M., & Gholami, P. (2019). Effects of Semi-Circular Bunds on Composition, Biodiversity, and Biomass Changes of Vegetation in Semi-Arid Rangelands of Bushehr Province. *Desert Ecosystem Engineering*, 8(4), 30-23.

Norklit, O., & Vaughan, R. G. (1998, November). Method to determine effective number of diversity branches. In IEEE GLOBECOM 1998 (Cat. NO. 98CH36250) (Vol. 1, pp. 138-141). IEEE.

O'Kelly, B. C. (2008, March). On the geotechnical design and use of peat bunds in the conservation of bogs. In *Proceedings of the International Conference on Geotechnical Engineering* (ICGE'08) (Vol. 24, p. 26th).

Pakistan, G. O. (2015). Economic survey of Pakistan. Economic Affairs Wing, Finance Ministry, Islamabad.

Saeed, A., Javed, M., Fazal, S., Ahsan, J., Khan, M. A., & Hassan, A. (2021). Study of ecosystem and.

Schwarz, M. (2012). Soilless culture management (Vol. 24). *Springer Science & Business Media*.
Shahbaz, M., Rafiq, M. K., & Khan, T. N. (2013). Arid Land Development and Combating Desertification in Pakistan. Combating Desertification in Asia, Africa and the Middle East: Proven practices, 231-248.
Sheikh, M. I. 1981. Dry afforestation experiments in Peshawar. *Pakistan Journal of Forestry*, 3:41-43.
Stegelmeier, A. A., Rose, D. M., Joris, B. R., & Glick, B. R. (2022). The use of PGPB to promote plant hydroponic growth*. Plants*, 11(20), 2783.
Siddiqui, T., Fattakh Nawaz, M., & Ahmed, I. (2010). Effect of different pruning intensities on the growth of *Acacia nilotica* (Kikar). *Agrociencia*, 44(1), 93-97.
Tadesse, B., Mesfin, S., Tesfay, G., & Abay, F. (2016). Effect of integrated soil bunds on key soil properties and soil carbon stock in semi-arid areas of northern Ethiopia. *South African Journal of Plant and Soil*, 33(4), 297-302.
Wolka, K., Moges, A., & Yimer, F. (2011). Effects of level soil bunds and stone bunds on soil properties and its implications for crop production: the case of Bokole watershed, Dawuro zone, Southern Ethiopia. *Agricultural Sciences*, 2(03), 357.