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Moisture use Response and Nodulation Effect on Chickpea (*Cicer arietinum* L.) to Conservation Approaches Like Land Configurations and Mulching

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ABSTRACT

The experiment was conducted at Agricultural College, Polasa, Jagitial, Professor Jayashankar Telangana State Agricultural University, Telangana, India during the *rabi* season (November, 2019–March, 2020) to study the influence of land configurations and mulching on moisture conservation and nodulation effect on chickpea (*Cicer arietinum* L.). Three land configurations were used in the experiment as the main plots namely; M_1- Flat bed, M_2- Ridge and furrow, M_3- Broad bed and furrow and four mulching treatments were used as subplots viz., S_1- Control, S_2- Sesamum mulch, S_3- Gliricidia mulch, S_4- Paddy straw mulch. The experiment was set up in a split plot design and was replicated thrice. Results revealed that the moisture content at different depths (0-15, 15-30, 30-45 cm) and at 20 days interval until 100 days, broad bed and furrow land configuration and Gliricidia mulch recorded higher moisture content compared to other treatments. Highest water productivity of (0.67 kg m^{-3}, 0.64 kg m^{-3}), root nodules per plant and dry weight of nodules per plant was recorded in broad bed and furrow land configuration and Gliricidia mulch respectively. Comparatively lowest water productivity, root nodules per plant and dry weight of nodules per plant was recorded in Flat bed land configuration and with no mulch.

Key words: *Land configurations, Split plot design, Sesamum, Paddy, Gliricidia.*

Introduction

Chickpea cultivation spans across more than 50 countries, with India emerging as the foremost global producer. In India, chickpeas contribute 49.3% to the overall pulse production in the year 2020–2021(ICRISAT, 2021). Globally, chickpea cultivation encompasses 149.66 mha, resulting in a total yield of 162.25 mt, with an average productivity of 1252 kg ha^{-1}, which makes chickpea as the third most important legume crop in the world (FAOSTAT, 2019; Tawffiq *et al.*, 2024). In India, despite its substantial production, there remains a pressing need to enhance productivity, primarily due to the extensive areas under cultivation and to achieve nutritional security (Merga and Haji, 2019; Samriti *et al.*, 2020).

Chickpeas are a rich source of nutrition, containing dietary fiber, protein, and carbohydrates. Additionally, they may help prevent cardiovascular disorders and possess anti-inflammatory, anti-tumor, anti-diabetic, and anti-cancer properties (Kaur and Prasad, 2021). Chickpea protein is often considered a favorable substitute for animal protein (Xu *et al.*, 2024). In India, the majority of rabi legumes are cultivated under rainfed conditions. Although chickpea is regarded as the drought-tolerant crop which is mostly grown in arid and semi-arid areas, some of the biggest obstacles to crop productivity are inadequate moisture supply and improper soil management (Dass and Bhattacharyya, 2017; Kumar *et al*., 2018; Korbu *et al*., 2020; Asma *et al*., 2021; Rajanna *et al.,* 2022). Prolonged drought stress at critical stages like reproductive and grain filling stages effects the growth and productivity of the crop and can reduce yields by 40–70% (Rani *et al.,* 2020; Nadeem *et al.,* 2019; Lu *et al*., 2021).

Land management through land configuration i.e. mechanical manipulation of the land surface and shaping of the seedbed, plays a crucial role in conserving maximum in-situ moisture and promoting root proliferation through infiltration while minimizing soil erosion (Haqmal *et al*., 2023; Subbulakshmi *et al*., 2024). This, in turn, facilitates more efficient water use by field crops, particularly in rainfed conditions, thereby buffering plants against drought stress and ultimately leading to higher productivity (Vekariya *et al*., 2015; Ashraf *et al*., 2020; Babu *et al.,* 2020).

Mulching conserves in-situ soil moisture (Ibrahim *et al.,* 2020; Sun *et al*., 2021). It also helps to control soil temperature, preserve soil structure, reduce soil erosion, decrease the evaporation and promote the biological activity (Ngosong *et al*., 2019; Bhargavi and Anusha, 2023; Demo and Bogale, 2024; Walia *et al*., 2024). Reduced soil and water losses with organic mulch have been reported by Tuure *et al.,* 2021 and Bugunovic *et al.,* 2023. If the source of mulch material is organic, farm waste can be utilized efficiently (Shirisha *et al.,* 2023). Furthermore, the organic mulches help in addition of the organic matter and nutrients to the soil, thus plays important role in nutrient cycle as well.

Legumes exhibit a symbiotic relationship with nitrogen-fixing bacteria called Rhizobia. These bacteria are housed within specialized root structures called nodules. Soil moisture and the root system are interdependent components, capable of disrupting crop growth factors, nodulation, and symbiotic nitrogen fixation under drought stress (Seki *et al*., 2007; Shrestha *et al*., 2021; Dollete *et al*., 2024).

Root architecture in the soil profile is vital for moisture uptake and nutrient supply to plants, governing crop growth and productivity (Yadav *et al*., 2018; Galindo-Castaneda *et al.,* 2022; Bardhan *et al.,* 2022). Root structure can be improved through appropriate management practices like land configuration and mulching.

The study primarily examines the impact of various land configurations and mulching treatments on soil moisture content at different depths over intervals of 20 days until crop maturity, water productivity and root nodulation in chickpea.

Materials and Methods

The field experiment was carried out during the *rabi* season (November, 2019-March, 2020) at Agricultural College, Polasa, Jagtial, PJTSAU, Telangana, India. Geographically, the farm is located at a height of 243.4 meters above mean sea level on latitudes of 18˜50′37.0″N and longitudes of 78 ˜57′00.6′′E. It is categorized under Northern Telangana Zone of Telangana State. The experimental soil was non-saline, with a texture of sandy clay loam and slightly alkaline in reaction. The experimental soil had low levels of organic carbon, low levels of available nitrogen, medium levels of available phosphorus, and high levels of available potassium.

The experiment was laid out in split plot design with three land configurations as main plots and four mulching treatments as sub plots and replicated thrice. The main plot treatments included were M_1- Flat bed, M_2- Ridge and furrow, M_3- Broad bed and furrow and sub plot treatments were S_1- Control, S_2- Sesamum mulch, S_3- Gliricidia mulch, S_4- Paddy straw mulch. In this case, ridges and furrows were placed 30 cm apart and 15 cm deep, broad beds and furrows were placed 90 cm apart and 30 cm deep, with the furrows being placed 15 cm above the ground. Five centimeters of mulch was covered over ground at a rate of 10 t ha^{-1} to the corresponding plots, which is adequate to protect the soil from external conditions.

A 30×10 cm^2 spacing was used for sowing the chickpea variety NBeG-3 at a rate of 65 kg ha^{-1}. Prior to planting, the seeds were treated with 3.5 g kg^{-1} of carbendazim and mancozeb, and 200 gms of rhizobium culture was inoculated per 8 kg of seed.

Soil moisture conserved due to land configurations and mulching was estimated by collecting the soil moisture content at three different depths i.e., 0-15, 15-30, 30-45 cm at 20 days interval through gravimetric soil sampling method using screw auger from date of sowing to physiological maturity. Soil moisture content (SMC) at each depth adopting gravimetric method was calculated using the formula.

$$SMC\ (\%) = \frac{(FW-DW)}{DW} \times 100$$

Where, FW is fresh weight of soil (g), DW is oven dry weight of soil (g).

Water productivity is defined as the average amount of output per unit of water applied in the field which was calculated using the formula.

$$WP = \frac{\text{Output (kg ha}^{-1})}{\text{Water applied (m}^{3}\text{ha}^{-1}).}$$

Number of nodules was counted in the roots of five sampled plants from gross plot at 30, 60 DAS and average number of nodules per plant was worked out.

Nodules collected from the five plants were dried in oven at 70±10 °C till the constant weight. Dry weight was divided by five to calculate the dry weight of nodules per plant. Nodules dry weight was calculated at 30 DAS and 60 DAS stages of crop growth.

The split plot approach was used to statistically evaluate the collected experimental data, and the F-test (Gomez and Gomez, 1984) was used to test the significance at the five percent probability level.

Results and Discussion

Soil moisture content

An insight on soil moisture contents at 20, 40, 60, 80 and 100 DAS are depicted in Fig. 1 - 2 at 0-15, 15-30 and 30-45 cm depths. It is observed from the data that there was an increase in the moisture content from 0-15 cm to 15-30 cm depth and a decreasing trend in the soil moisture content from 30-45 cm. This might be due to presence of more clay content in the 15-30 cm depth compared to 30-45 cm depth.

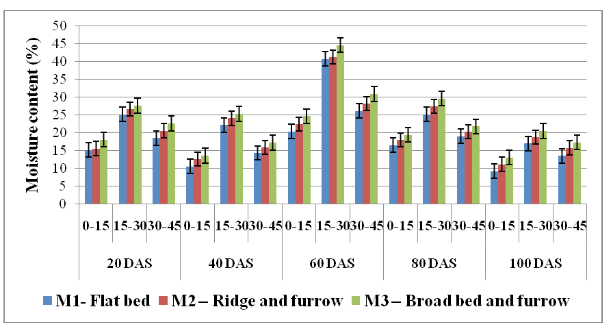

Fig. 1. Moisture content (%) at different depths and intervals as influenced by land configurations

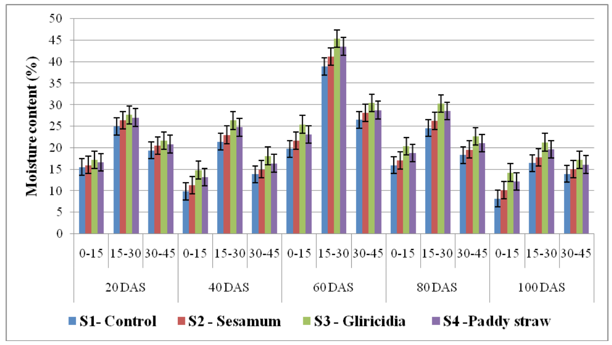

Fig. 2. Moisture content (%) at different depths and intervals as influenced by mulching

At 20 DAS, broad bed and furrow configuration at 0-15 cm depth resulted in highest moisture (18.17%), followed by ridge and furrow (15.64%) and the lowest moisture content was recorded in flat bed (15.23%) which was on par with ridge and furrow land configuration. At 15-30 cm depth, the moisture content was found to be non-significant, but broad bed and furrow configuration was found to conserve more moisture with 27.70% compared to others. At 30-45 cm depth, the moisture conservation was found to be significant with highest moisture found to be conserved in broad bed and furrow (22.72%), followed by ridge and furrow (20.63%). The moisture content in ridge and furrow and flat bed was found to be on par with each other. The difference in moisture conservation at different depths at same duration may be due to the presence of most of the clay contents at 15-30 cm depth and with the different configurations.

There was no significant difference in moisture contents under different mulch treatments at 0-15 cm, 15-30 cm and 30-45 cm depth (20 DAS). This may be due application of mulch at 15 DAS, which takes time to show its influence.

The similar trend of moisture conservation was observed at all the intervals with different land configurations i.e., broad bed and furrow > ridge and furrow > flat bed and with different mulches i.e., Gliricidia> paddy straw > sesamum mulch > control. Better performance of different land configurations may be due to the better structure provided to suit the soil type. Better coverage provided by the different mulches may attribute to difference in moisture conservation.

At 40 DAS, there was a decrease in moisture content in the soil compared to 20 DAS which might be due to irrigation, which was not applied to the field in between the interval, evaporation of moisture from the soil and usage of moisture by the plants for metabolic activities. Significantly highest moisture was conserved in broad bed and furrow (13.65%, 25.33%, 17.27%) at 0-15, 15-30 and 30-45 cm depth and the least in flat bed (10.62%, 22.28%, 14.40%) at 0-15, 15-30 and 30-45 cm depth respectively. Ridge and furrow method performed on par with broad bed and furrow at 0–15, 15-30 cm. Among mulching treatments, Gliricidia mulch conserved significantly highest moisture (14.81%, 26.38%, and 18.12%) at 0-15, 15-30 and 30-45 cm depth respectively. The least moisture conservation was observed in control (9.90%, 21.47% and 13.88%) at 0-15, 15-30 and 30-45 cm depth respectively.

At 60 DAS, there was an increase in the soil moisture content compared to 40 DAS, which might be due to application of irrigation in between the interval and occurrence of rainfall. There was a significant difference in moisture content at 15-30 cm, 30-45 cm depth except at 0-15 cm depth. The highest moisture was conserved in broad bed and furrow (24.73%, 44.70% and 30.96%) at 0-15, 15-30 and 30-45 cm depth. The lowest soil moisture was conserved under flatbed (20.37%, 40.82% and 26.19%) at 0-15, 15-30 and 30-45 cm depth respectively. The soil moisture content in flatbed was on par with ridge and furrow at 15-30 cm depth. Among mulching treatments, Gliricidia mulch conserved significantly highest moisture (25.48%, 45.38%, 30.45%) at 0-15, 15-30 and 30-45 cm depth. At 0-15 cm and 30-45 cm depth, the soil moisture content in sesamum mulch was on par with paddy straw mulch and at 15-30 cm depth, paddy straw mulch performed on par with Gliricidia mulch.

There was a decreasing trend in moisture content at 80 DAS and100 DAS, as there was no irrigation applied thereafter and no rainfall events occurred. Significantly, highest moisture conservation was recorded in broad bed and furrow (19.50%, 29.70% and 21.83%) at 0-15, 15-30 and 30-45 cm depth at 80 DAS and (13.17%, 20.53%, 17.39%) at 0-15, 15-30 and 30-45 cm depth respectively at 100 DAS. Among mulching treatments, Gliricidia conserved significantly highest moisture (20.36%, 30.31% and 22.69%) at 0-15, 15-30 and 30-45 cm depth at 80 DAS and (14.24%, 21.27% and 17.22%) at 0-15, 15-30 and 30-45 cm depth respectively at 100 DAS.

Lower soil moisture content in surface layers (0-15 cm) compared to sub surface layers was noticed by Yadav *et al*. (2018).The results are in agreement with the findings of Khatri *et al***.** (2002) and Singh *et al*.(2008) for land configurations. Mulching reduces soil temperature and also acts as a physical barrier between environment and soil surface and reduces the heat exchange resulting in cooler soil micro climate and higher moisture content compared to control i.e., no mulch (Kumar *et al*., 2020, Eruola *et al*., 2012 and Sinkeviciene *et al*., 2009).

The interaction between land configurations and mulching for moisture content was found to be non-significant at all the depths and intervals.

Water productivity (kg m^{-3})

Water productivity is an indicator for kg grain produced for m^3 of water applied to the crop. The data pertaining to water productivity as influenced by land configurations and mulching is presented in Table 1. The total water applied in the current research during the crop period was 2141.20 m^3 in two irrigations given on 21-12-2019 and 25-01-2020 to which treatments responded differently and the water productivity ranged between 0.45 kg m^{-3} to 0.67 kg m^{-3}.

Table 1. Water productivity (Kg m^{-3}) of chickpea as influenced by land configurations and mulching

Treatment	Water productivity (Kg m^{-3})
Main plot (Land configuration)	
M_1- Flat bed	0.45
M_2- Ridge and furrow	0.57
M_3- Broad bed and furrow	0.67
SEm±	0.02
CD (P=0.05)	0.06
Sub plot (Mulching)	
S_1 - Control	0.49
S_2- Sesamum@ 10 t ha^{-1}	0.54
S_3 - Gliricidia@ 10 t ha^{-1}	0.64
S_4 -Paddy straw@ 10 t ha^{-1}	0.58
SEm±	0.02
CD (p=0.05)	0.05
Interaction	
SEm± (M×S)	0.03
CD (p=0.05)	NS
SEm± (S×M)	0.03
CD (p=0.05)	NS

Broad bed and furrow land configuration recorded significantly highest water productivity (0.67 kg m^{-3}), followed by ridge and furrow (0.57 kg m^{-3}). The difference in the treatments may be due to the difference in the yield, which ultimately effected by the moisture content and the better crop environment provided by different land configurations.

Among different mulching treatments, Gliricidia recorded significantly highest water productivity (0.64 kg m^{-3}) over paddy straw mulch (0.58 kg m^{-3}) and Sesamum mulch (0.54 kg m^{-3}) which was on par with paddy straw mulch. The least water productivity was recorded in control treatment (0.49 kg m^{-3}) which is on par with Sesamum mulch. Better moisture conservation might be the reason for better performance of Gliricidia mulch over other mulch. Interaction effect between land configuration and mulching for water productivity was found to be non-significant.

Improved water productivity with bed planting was observed by Devkota *et al.* (2021) citing the movement of top soil from furrows to beds adds the fertile soil on to top of the beds in the process of layout of beds, which makes plants respond more to nutrients along with moisture conservation resulting in better water productivity.

Water productivity under straw mulching and ridges and furrows was higher compared to no mulch and no land gradient treatments was observed by Zheng *et al.* (2021) relating the reason to high soil water availability.

Root nodules plant^{-1} (Number)

The data pertaining to root nodule number per plant as influenced by land configuration and mulching at different intervals is presented in Table 2.

Significantly, higher number of root nodules per plant was recorded with broad bed and furrow (5.48 and 31.31), followed by ridge and furrow method and the least number of nodules per plant was recorded under flatbed cultivation at 30 DAS and 60 DAS respectively. Difference in nodulation under different land configurations was due to lose and friable rhizosphere with good aeration provided by various land configurations (Parihar *et al.*, 1999).

Among different mulching treatments, Gliricidia mulch recorded significantly higher number of nodules over other mulches. Significantly, highest nodule number was recorded with Gliricidia (5.42 and 32.66 nodules plant^{-1}) at 30 DAS and 60 DAS, followed by paddy straw mulch at 30 DAS and 60 DAS and Sesamum mulch at 30 DAS and 60 DAS respectively. Nodulation in the land configuration is governed by soil structure associated with micro climatic conditions of soil which can be improved with mulching. Similar, results were also reported by Bhargav *et al.*, 2018; Li *et al.*, 2021. The interaction for root nodule per plant, between land configuration and mulching was found to be non-significant.

Dry weight of root nodules plant^{-1}(mg)

Data pertaining to dry weight of root nodules per plant is presented in Table 2. Land configurations

Table 2. Root nodules plant^{-1}and dry weight of root nodules plant^{-1} (mg) as influenced by land configurations and mulching in chickpea

Treatment	Root nodules plant^{-1} (Number)		Dry weight of root nodules plant^{-1} (mg)	
	30 DAS	60 DAS	30 DAS	60 DAS
Main plot (Land configuration)				
M_1- Flat bed	4.19	24.72	0.45	7.30
M_2- Ridge and furrow	4.76	27.92	0.49	8.17
M_3- Broad bed and furrow	5.48	31.31	0.53	9.14
SEm±	0.14	0.54	0.01	0.21
CD (P=0.05)	0.54	2.12	0.03	0.84
Sub plot (Mulching)				
S_1 - Control	4.21	23.63	0.43	6.95
S_2- Sesamum@ 10 t ha^{-1}	4.60	26.16	0.47	7.81
S_3 - Gliricidia@ 10 t ha^{-1}	5.42	32.66	0.55	9.46
S_4 -Paddy straw@ 10 t ha^{-1}	5.00	29.47	0.51	8.59
SEm±	0.13	0.49	0.01	0.22
CD (P=0.05)	0.37	1.46	0.02	0.64
Interaction				
SEm± (M×S)	0.22	0.85	0.01	0.37
CD (P=0.05)	NS	NS	NS	NS
SEm± (S×M)	0.23	0.91	0.01	0.39
CD (P=0.05)	NS	NS	NS	NS

and mulching had significant effect on dry weight of root nodules per plant recorded at 30 DAS and 60 DAS.

Broad bed and furrow method recorded significantly highest dry weight of root nodules per plant (0.53 mg, 9.14 mg) at 30 DAS and 60 DAS, followed by ridge and furrow land configuration at 30 DAS and 60 DAS respectively. The lowest dry weight of root nodules per plant was recorded under flatbed sowing with 0.45 mg at 30 DAS and 7.30 mg at 60 DAS.

Among mulching treatments, Gliricidia mulch recorded significantly highest dry weight of nodules per plant (0.55 mg, 9.46 mg) at 30 DAS and 60 DAS over paddy straw mulch and sesamum mulch at 30 DAS and 60 DAS respectively. The difference in performance of treatments may be due to presence of more soil moisture, increased porosity, number and size of root nodules. These results are in agreement with the findings of Li *et al.,* 2021. Similar results were reported in cowpea by Masete *et al.* (2022) and Ingole *et al*. (1998).

The interaction effect for dry weight of root nodules at 30 DAS and 60 DAS between land configurations and mulching was found to be non-significant.

Conclusion

Broad bed and furrow land configuration and Gliricidia mulch significantly affected moisture content, root nodules per plant, dry weight of root nodules per plant and water productivity. Performance of land configurations could be attributed to improved soil moisture conservation, enhanced soil structure and presence of friable rhizosphere with good aeration. Organic mulching moderated soil temperature, decreased evaporation and enhanced soil micro-climate. Land configurations and mulching are effective strategies for moisture conservation and nodulation enhancement in chickpea.

Conflict of Interest- None

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