

Influence of different levels of hydrogel on root nodulation in Chickpea (*Cicer arietinum* L.)

Abstract

This study investigated the impact of varying levels of hydrogel on the root nodules of Chickpea (*Cicer arietinum* L.) during Rabi seasons of 2019-20 and 2021-22 at the Department of Biological Sciences, Sam Higginbottom Institute of Agriculture, Technology, and Sciences, (U.P). The experimental design was a randomized block design, featuring four levels of hydrogel and two levels of irrigation, with treatments replicated thrice. Observations on the number of nodules per plant, active nodules, and inactive nodules were recorded at 30, 60, and 90 days after sowing (DAS) and at maturity. The results indicated that hydrogel application significantly affected nodule formation at all growth stages across both years. The highest number of nodules, active nodules, and inactive nodules were recorded in treatment T₁₀ (2 irrigations + 100% hydrogel), followed by T₉ (2 irrigations + 75% hydrogel), in both years. The enhanced nodule formation with hydrogel application was attributed to improved water availability to the roots during periods of water scarcity, highlighting hydrogel's role in optimizing nitrogen availability and promoting chickpea growth, which is crucial for enhancing soil fertility.

Introduction

Nitrogen fixation of leguminous plant is an important aspect of sustainable agriculture by which the atmospheric N₂ is converted to ammonia with the aid of a key enzyme called nitrogenase (Udvardi and Poole, 2013, Oldroyd *et al.*, 2011). It is achieved by bacteria inside the cells of *de novo* formed organs, the nodules, which usually develop on roots of various leguminous plants. This process is resulted from the complex interaction between the host plant and rhizobia. The chickpea, like other legumes, is important for environmentally friendly and sustainable farming. It may form a symbiotic relationship with rhizobia that can convert atmospheric nitrogen into ammonia that plants can directly absorb, increasing the productivity of this crop and succeeding cereal crops and enhancing soil fertility by fixing nitrogen at rates of up to 140 kg/ha/year (Flowers *et al.*, 2010), decreases the need of chemical fertilisers greatly, which lowers the amount of greenhouse gas emissions and water pollution per hectare each year (De la Pena and Pueyo, 2012). By boosting the synthesis of

phytohormones and mineral absorption, several rhizobial strains have been shown to be able to stimulate plant growth and development (Karthik *et al.*, 2017). Chickpea is regarded as a host that restricts nodulation (Rivas *et al.*, 2007; Laranjo *et al.*, 2008; Suneja *et al.*, 2016). The availability of nitrogen in agriculture has a significant impact on both output and product quality. In the natural world, plants either assimilate nitrate and ammonium or get nitrogen from di-nitrogen by collaborating with bacteria that fix nitrogen. The most significant symbiosis in terms of biological nitrogen fixation is between legumes and rhizobia, which together produce roughly 200 million tonnes of nitrogen annually (Graham and Vance, 2003; Peoples *et al.*, 2009). The bacterial microsymbionts enter individual plant cells and settle in compartments encircled by a plant membrane to form a symbiosis necessary for nodulation (Jens Stougaard, 2000). Although the symbiotic nitrogen (N) fixation between legumes and Rhizobium is a crucial biological characteristic and the cornerstone of increasing soil fertility, there are currently few efficient rhizobial inoculants that can adapt to salinized soils. Previous research has demonstrated that drought and salt stress significantly reduced plant biomass accumulation (root and shoot), nodule growth, nitrogenase activity, and chickpea production (Garg and Baher, 2013; Egamberdieva *et al.*, 2014). Due to their deeply penetrating roots, which allow them to make use of the scarce moisture that is available; chickpeas can improve the fertility of the soil (Tripathi *et al.*, 2015).

Material and methods:

The field experiment of present investigation entitled “Impact of different levels of hydrogel on root nodules of Chickpea (*Cicer arietinum* L.)” was conducted during Rabi 2019-2020 and 2021-2022 under Department of Biological Sciences, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad (U.P). The climate of the experimental site is characterised by semi-arid type with hot and dry summer from April to June, hot and humid from July to September and cold winter from November to January. The experiment was conducted by the randomised block design with combinations of four level of hydrogel and two level of irrigation i.e. T₀ (3 irrigation), T₁(1 irrigatin) T₂(1 irrigation + 25% hydrogel) T₃(1 irrigation + 50% hydrogel), T₄(1 irrigation + 75% hydrogel), T₅(1 irrigation + 100% hydrogel), T₆(2 irrigatin) T₇(2 irrigation + 25% hydrogel), T₈(2 irrigation + 50% hydrogel), T₉(2 irrigation + 75% hydrogel), T₁₀(2 irrigation + 100% hydrogel) are replicated thrice. During the crop growth period, the following observations were recorded time to time. Number of nodules/plants: After digging out three plants from randomly in each plot, the number of nodules were counted at regular intervals of 30, 60, 90 DAS and at

Comment [u1]: Correct spelling as irrigation

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maturity. Active nodules: Active nodules were counted on the basis of colour of the nodules. Inactive nodules: Inactive nodules were counted by subtracting Active nodules from Total number of nodules. Fisher's ANOVA technique and least significance difference (LSD) test at 5% probability level were used to compare differences among treatment means.

Comment [u3]: Also analysed the data at 1% significance level

Result and discussion:

The effect of application of hydrogel was found to be significant at 30DAS, 60 DAS, 90 DAS and at maturity in both the years. The maximum no. of Nodules 24.82, 32.37, 25.0 and 24.5 were recorded in treatment T₁₀ in the year 2020, 2021 and in pooled respectively and followed by treatment combination T₉ which is at par and recorded No. of Nodules in both the years respectively.

Comment [u4]: Also write significance level

The effect of application of hydrogel on No. of Active Nodules was found to be significant at 30DAS, 60 DAS, 90 DAS and at maturity in both the years. The maximum No. of Active Nodules 22.52, 30:20.13:19 was recorded in treatment T₁₀ in the year 2020, 2021 and in pooled respectively and followed by treatment combination T₉ which is at par and recorded No. of Active Nodules in both the years respectively.

Comment [u5]: Write in running font instead of No. Write Number at all places

The effect of application of hydrogel on No. of Inactive Nodules was found significant at 30DAS, 60 DAS, 90 DAS and at maturity in both the years. The maximum No. of Inactive Nodules 3.52, 5.23, 9.17 and 7.82 was recorded in treatment T₁₀ in the year 2020, 2021 and in pooled respectively and followed by treatment combination T₉ which is at par and recorded No. of Inactive Nodules in both the years respectively.

This may be due to the availability of water to the roots through hydrogel during water scarcity to the plants. The availability of nitrogen in agriculture has a significant impact on both output and product quality (Graham and Vance, 2003; Peoples *et al.*, 2009). Chickpeas possess deeply penetrating roots that enable them to access and utilize the limited moisture available in the soil, making them valuable for improving soil fertility (Tripathi *et al.*, 2015).

Table 1. Influence of different levels of hydrogel on root nodules of Chickpea (*Cicer arietinum* L.)

Treatments	No. of nodules (Nos)				No. of active nodules (Nos)				No. of inactive nodules (Nos)			
	30DAS	60DAS	90DAS	At harvest	30DAS	60DAS	90DAS	At harvest	30DAS	60DAS	90DAS	At harvest
T ₀	21.12	26.23	23.13	21.77	19.42	24.37	17.35	14.9	1.7	1.85	5.77	6.82
T ₁	13.6	18.27	14.83	14.37	10.08	16.4	7.45	6.67	3.52	1.88	7.38	7.68

T₂	13.47	19.4	14.3	14	10.92	18.5	8.1	7.27	2.55	0.93	6.2	6.72
T₃	13.73	20.2	14.9	14.5	11.45	18.63	8.33	7.67	2.28	1.58	6.55	6.82
T₄	13.2	20.4	14.5	13.8	11.72	18.13	8.7	8.13	1.48	2.28	5.8	5.62
T₅	14.13	20.73	15.17	14.63	12.18	17.2	9.2	8.7	1.95	3.53	5.97	5.92
T₆	14.93	24.33	16.47	16.2	12.83	19.13	9.23	8.35	2.1	5.23	7.23	7.82
T₇	20.93	24.3	19.37	19.7	17.45	20.2	10.2	9.57	3.48	4.12	9.17	10.1
T₈	24.18	30.33	24.13	23	20.8	27.4	18.23	17.3	3.38	2.95	5.88	5.7
T₉	23.25	31.03	24.53	23.7	21.4	28.93	19.18	17.52	1.85	2.1	5.32	6.17
T₁₀	24.82	32.37	25.0	24.5	22.52	30.0	20.13	19.0	2.3	2.37	4.87	5.47
C.D.	0.91	2.45	1.91	2	0.43	1.77	0.19	0.93	0.97	1.49	1.98	2.2
SE(m)	0.31	0.82	0.64	0.67	0.15	0.6	0.06	0.31	0.33	0.5	0.67	0.74
SE(d)	0.44	1.17	0.91	0.95	0.21	0.84	0.09	0.44	0.46	0.71	0.94	1.05
C.V.	2.97	5.87	5.94	6.42	1.62	4.75	0.88	4.74	23.3	33.07	18.14	18.89

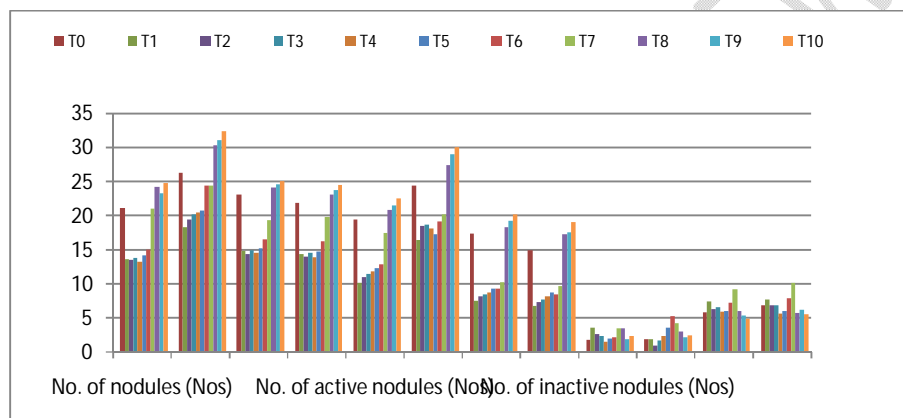


Fig. 1 Influence of different levels of hydrogel on root nodules of Chickpea (*Cicer arietinum* L.)

Conclusion

The results of present study concluded that hydrogel application significantly affected nodule formation at all growth stages across both years. The highest number of nodules, active nodules, and inactive nodules were recorded in treatment T₁₀ (2 irrigations + 100% hydrogel), followed by T₉ (2 irrigations + 75% hydrogel), in both years. The enhanced nodule formation with hydrogel application was attributed to improved water availability to the roots during periods of water scarcity, highlighting hydrogel's role in optimizing nitrogen availability and promoting chickpea growth, which is crucial for enhancing soil fertility.

References:

Comment [u6]: In conclusion also write the highest significant data as compared to control or T₀

Comment [u7]: Complete the references as per the journal format

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General comments by reviewer:

1. Elaborate the methodology part.
2. Add some photographs of the experimentation.
3. Add the data on physicochemical characteristics of soil.
4. Add meteorological data of the study area.
5. Test the data at 1% significance level also.

Recommended for the revision of the manuscript

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